Functional outcome of extra-articular distal tibia fractures treated with Minimally Invasive Plate Osteosynthesis

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE TAMILNADU **DR. M. G. R. MEDICAL UNIVERSITY,** TAMIL NADU, CHENNAI FOR THE DEGREE OF **M.S. ORTHOPEDICS** TO BE HELD IN APRIL 2014.

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ENDORSEMENT BY HEAD OF DEPARTMENT AND PRINCIPAL OF INSTITUTION

This is to certify that this dissertation entitled "**FUNCTIONAL OUTCOME OF EXTRA ARTICULAR DISTAL TIBIA FRACTURES TREATED WITH MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS"** is a bonafide research work done by **Dr. Smruti Ranjan Panda,** under the guidance of **Dr. Thilak Jepegnaman,** Professor, Department of orthopaedics Unit 3, Christian Medical College Hospital, Vellore.

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This is to certify that the dissertation entitled "**FUNCTIONAL OUTCOME OF EXTRA ARTICULAR DISTAL TIBIA FRACTURES TREATED WITH MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS"** is the bonafide work by **Dr. Smruti Ranjan Panda** in the partial fulfillment of the requirement for the M.S. Degree (Orthopedics) of the Tamil Nadu Dr. M.G.R. Medical University ,Chennai to be held in April 2014.

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ABSTRACT

TITLE OF THESIS: Functional outcome of extra articular distal tibia fractures treated with minimally invasive plate osteosynthesis.

DEPARTMENT: Department of Orthopaedics Unit 3, C.M.C. Hospital, Vellore

NAME OF CANDIDATE: Dr. Smruti Ranjan Panda

DEGREE AND SUBJECT: Masters in Orthopaedics (Two year, Post Diploma)

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OBJECTIVES:

The purpose of this research is to study whether minimally invasive plate osteosynthesis leads to consistent union and early return to work. The specific objectives included :

1) Correlation between the functional scores and radiological parameters of distal thirds diaphyseo - metaphyseal tibial fractures treated by minimally invasive plate osteosynthesis along with the time to bony union and

2) Documentation of the major and minor complications associated with this treatment modality.

METHODS: A retrospective study was performed on patients who underwent minimally invasive plate osteosynthesis of their distal tibia fracture in Department of Orthopaedics Unit 3 from January 2008 to December 2011. Demographic data such as mechanism of injury, level and pattern of the tibia and fibula fracture, associated injuries, duration between injury and treatment and length of follow-up were recorded from the hospital records. The patients were then requested to come to the hospital for a routine visit. Consent was obtained from the respective patients and a detailed clinical assessment was done by the two examiners independently followed by specific functional scores and measurement of radiograph parameters.

The functional outcome was measured by using standard questionnaires and consisted of the AOFAS (American Orthopaedic Foot and Ankle Society score & Olerud and Molander scores and were then graded as excellent/ good/ fair and poor and compared to similar studies by other authors.

Radiographic assessment was done comparing the anteroposterior and lateral views of the affected and the normal leg with both the knee and ankle joint included and the time to union, malunion and shortening were documented.

All major and minor complications were documented at follow up.

RESULTS :

22 patients (84.7%) had uneventful healing of the fractures. Delayed union and infection occurred in two patients each (7.5%). All fractures healed without the need of any secondary procedures. There was no noticeable mal- alignment or non-union. Functional outcome was good to excellent in all patients. Average time to bony union was 24 weeks.

CONCLUSIONS :

MIPO allowed uneventful healing and restoration of the pre-injury level of function in most patients.

Contents

Introduction

The process of rapid and unplanned urbanization has resulted in an unprecedented revolution in the growth of motor vehicles worldwide. The alarming increase in morbidity and mortality owing to road traffic accidents over the past few decades is a matter of great concern globally. Currently motor vehicle accidents ranks ninth in order of disease burden and are projected to be ranked third in the year 2020(1). Worldwide, every year almost 1.2 million people killed in road traffic, while the number of people that are injured could be as high as 50 million(1).

In India, over 80,000 persons die in the traffic crashes annually, over 1.2 million are injured seriously and about 300000 disabled permanently. For individuals more than 4 years of age, more life years are lost due to traffic crashes than due to cardiovascular diseases or neoplasms. The highest number of deaths due to road accidents during the years were reported in Tamil Nadu (11.6%) followed by Uttar Pradesh (10.9%), Andhra Pradesh (10.8%) and Maharashtra (10.0%). The wage-earning age group comprised of more than half of the road traffic casualties(2).

Fractures are the commonest injury among the victims of non-fatal road traffic accidents and it commonly involves the bones of the lower extremity. This can be due to the interplay of gravitational force and velocity of the vehicle at the time of accidents.

Tibial fractures are the most common type of long bone fractures and are the most common open ones too. On the basis of the fracture location in the bone, distal tibia fractures have the second highest incidence of all tibia fractures(3). The relatively tenuous blood supply, subcutaneous location of the tibia, mechanism of injury, and use of certain treatment methods contribute to a relatively high incidence of post traumatic complications following tibia fractures[4]. These complex open fractures which are produced by high energy forces, threaten to pose a challenge to orthopaedic surgeons. Considerable advances in the methods and concepts of internal fixation along with newer innovations in implants help to meet such challenging tasks.

The landmark paper by Ruedi and Allgower (1969)[5] which showed 74% of their patients pain free and with good functional outcome at four years follow-up, revolutionized the management of distal tibia fractures. Thereafter, the 1970's and 1980's witnessed widespread application of the principles of ORIF in the management of distal tibia fractures. However, this was accompanied by a shockingly high rate of major complications including non-union up to 18%, superficial infections up to 20%, osteomyelitis up to 17%, arthrodesis rates of 27%, below knee amputation rates of 6%, post-traumatic osteoarthrosis rates of 54% and mal-unions in 42% of patients[6] [7]. These high rates of complications made surgeons to realise the importance of soft tissue management in distal tibia fractures. Further analysis of Ruedi and Allgower's series at 9 years follow up still showed good results ,[8] but most of the patients in his series had low-energy injuries. They presented another series [9] in 1979 which consisted of high-energy injuries and found that the overall results were not as good as those in patients with lower-energy injuries. This led many authors to conclude that incorporation of both fixation of fracture along with the avoidance of soft tissue complications yielded better results [10][11]. Therefore the ideal method of treatment is one that would achieve a good reduction and stability while minimizing soft tissue compromise and devascularization of the fracture fragments. Consequently, new tactics were utilized for the management of distal tibia fractures namely: delayed ORIF, limited ORIF, hybrid fixators and biological osteosynthesis [minimally invasive plate osteosynthesis – MIPO].

In biological osteosynthesis, the fracture hematoma and soft tissue attachment of the comminuted fragments are not disturbed, thereby preserving the osteogenic capacity and vascularity of the fragments. The fracture site is stabilized by fixing the plate to the proximal and distal major fragments by minimal soft tissue dissection. Rotational and angular alignment and limb length are restored by indirect reduction, thereby improving the functional outcome. In biological internal fixation recognition of the optimum requirements for bone healing now takes precedence, with mechanical stabilisation being less rigid while still allowing painless function and reliable healing.

This retrospective study with a prospective follow up of 26 patients evaluates our experience with minimally invasive plate osteosynthesis for distal tibia fractures.

Aims and objectives

Objective : To study the functional outcome of patients with extra-articular distal thirds diaphyseo-metaphyseal tibial fractures treated by minimally invasive plate osteosynthesis .

AIM 1: To document time to bony union.

AIM 2: To document and correlate the functional scores and radiological parameters of distal thirds diaphyseo-metaphyseal tibial fractures treated by minimally invasive plate osteosynthesis.

AIM 3: To document the major and minor complications associated with this treatment modality.

Our **Hypothesis** was that minimally invasive plate osteosynthesis led to consistent union and earlier return to work.

Review of literature

HISTORICAL REVIEW

Plate osteosynthesis was first reported more than a century ago by C. Hansmann[12] , a German surgeon from Hamburg. The development of asepsis and antiseptic operating theatre rooms' conditions led to further development of fixation methods.

The initial plates were too weak to provide sufficient stabilization. The implant design and composition were further improved to augment its strength. When AO/IF first introduced the concept on internal fixation of fractures their tenets included anatomic reduction and rigid fixation. By adhering to these techniques and developing a unique set of instruments and implants, the AO/ASIF group showed good union rates in simple fractures[13]. However the improved implant design and material properties neglected the biological aspects and reaction of the cortical bone adjacent to the plate. In 1988 Stephan Perren stated that the porosis which was initially attributed to stress protection, was found to be the result of the accelerated remodelling of necrotic cortical bone [14].

This resulted in the production of plates designed to decrease their contact with bone (limited contact, point contact), causing less interference to the vascularization of the adjacent cortical bone and therefore less necrosis. The poor results of anatomic reduction and rigid fixation led to the development of biological fixation, where a reasonable fracture reduction acceptable.

Further evidence of fracture healing without absolute stability came from the fact that fractures with flexible fixation like splints, external fixators and bridge plating also lead to bony healing with callus formation. In fact indirect healing often leads to faster healing and better bony union. Even multifragmentary fractures held by bridge plating demonstrated high union rates without the need for bone grafting.

This was explained by the concept of Interfragmentary strain(15) .

Concept of interfragmentary strain : Single narrow gaps are intolerant of even minute amount of displacement due to displacement of repair tissues while multifragmentary fractures can tolerate greater degree of instability as overall displacement is shared between many fracture gaps.

Thus the stage was set for the progression to more biological methods of fracture fixation namely Minimally Invasive Osteosynthesis.

Minimally invasive fracture fixation was first introduced with external fixator by the Belgian surgeon Albin Lomboette(16) at the beginning of the 20th century. Intramedullary nailing by Gerhardt Kuntscher(17) during World War II , improvised small skin incisions and indirect reduction techniques that lead to indirect bone healing with callus formation.

In 1990 Jeff W. Mast and Reinhold Ganz created the term “ Biological plating ” to describe indirect reduction techniques in applying blade plates around the epiphysiometaphyseal areas as extramedullary splints (18). Thus a biomechanically stable construct with the individual bone fragments left untouched.

The advent of Point Contact Fixator (19) in 1993 and Less Invasive Stabilization System [LISS](20) in 1995 which were specifically designed for juxta-articular fractures, provided angular stability along with preservation of both the periosteal and endosteal blood supply of the fractured bones. The LISS is an internal fixator taking advantage of locked full-length metaphyseal screws, and a combined plate allowing for compression fixation and/or locked internal fixation [21]. LISS could be considered the first plate that was specifically designed and instrumented for application using a minimally invasive sub-muscular approach as it has its own insertion handle which facilitated the introduction of the implant sub-muscularly and at the same time acts as a drill guide for accurate insertion of the screws through separate small stab wounds.

In 1997 Christian Krettek [22] while using minimal invasive techniques in applying D.C.S plates for the distal femur coined the term Minimally Invasive Plate Osteosynthesis (M.I.P.O), which resulted in fewer complications as compared to the traditional open access surgery. He also stated that it was technically demanding and that limb alignment must be properly handled.

In 1997, Helfet [23] performed M.I.P.O. for the first time in the distal tibia region and described it as a feasible method of stabilization, while avoiding severe complications.

The advent of LCP with combination holes, variable angle locked plates[24] and various anatomical plates for different anatomical regions made MIPO more reliable and successful.

The current AO recommendation for minimally invasive osteosynthesis [25] includes :

- Small window to allow implant insertion remote from the fracture site.

- Indirect reduction of fracture with careful and minimal soft tissue handling.

- Special instruments if required at fracture site (MIPO cerclage passer / Collinear reduction clamp)

The main problem of MIPO technique is the reduction of the fracture (no direct manipulation is possible) and the intra operative assessment of the fracture reduction (no direct visualization). Most of the complications that occur in the MIPO technique are mal-alignment, either malrotation or angulation, and limb length discrepancy. They occur resulting from technical errors that are preventable.

In the last decade many clinical non randomized case series from different anatomical regions have been published to illustrate that MIPO technique has higher fracture healing rates, smaller complications as well as low amounts of malreductions and malalignments [(26-40)].

As a conclusion of the above studies, MIPO technique has been proven to be reliable and satisfactory results are achieved in terms of soft tissue healing, fracture union rates as well as functional outcome.

Thus summarizing the principles of minimally invasive plate osteosynthesis:

1) Minimize iatrogenic soft tissue disruption.

2) Utilize indirect reduction techniques (align the two major or parent fracture fragments in a functional position without precise anatomical reconstructing of the individual fracture fragments).

3) Provide stable fixation.

4) Promote the early return to limb function

Minimally invasive plate osteosynthesis doesn’t disturb the fracture hematoma and leaves periosteum intact with soft tissue attachment of bone fragments. This preserves and maintains pluriopotent mesenchymal cells capable of giving rise to osteoblastic progenitor cells and retains the vascularity of the fracture fragments.

The plate osteosynthesis gives sufficient stability, so that early mobilization can be started. Early mobilization imparts functional load and strain within critical limits which in turn promotes callus formation. This also contributes to improved functional outcome.

The balance between the degree of invasiveness and the achieved quality of reduction and stability is often difficult to define and must be related to several factors (anatomical region and type of fracture, local soft tissue conditions, quality of the bone, age and requirements of the patient, available implants, experience and preference of the surgeon, etc.).New technologies such as improved imaging, intraoperative computer navigation and percutaneous reduction tools will help to further improve the effectiveness of minimally invasive surgery in the near future.

BIOLOGICAL ASPECTS OF HEALING :

Fracture healing is a sequence of inflammation, repair and remodelling. Immediately after fracture, hematoma forms between the fragments and beneath the elevated periosteum. Inflammatory mediators released from the platelets and injured tissues induce neoangiogenesis. As this phase ends the necrotic tissue is removed and fibroblasts appear and produce new matrix.

The repair phase is started by organisation of fracture hematoma. Experimental works have shown that loss of hematoma slows fracture healing. The hematoma, intake periosteum and soft tissue envelope form a tube which facilitates fracture healing. Often reduction particularly anatomical reduction may disturb this, thereby retarding the healing process.

The inflammatory mediators recruit pluripotent mesenchymal cells and induce them of differentiate into fibrous, cartilaginous and osseous lineage. The source of the mesenchymal cells is the injured tissue and new blood vessels. The osteoblasts from the endosteal surface also contribute to callus formation. These facts emphasize the protection of the intact periosteum and the new blood vessels.

Thus the new bone formation results in the formation of fracture callus. This callus is less stiff and hence deforms under load.

The reparative phase is followed by remodelling phase which converts the soft fracture callus into hard callus and ultimately into lamellar bone of sufficient stiffness to endure physiologic loads. This takes considerably long time.

BIO-MECHANICS OF FRACTURE HEALING IN COMMINUTED FRACTURES

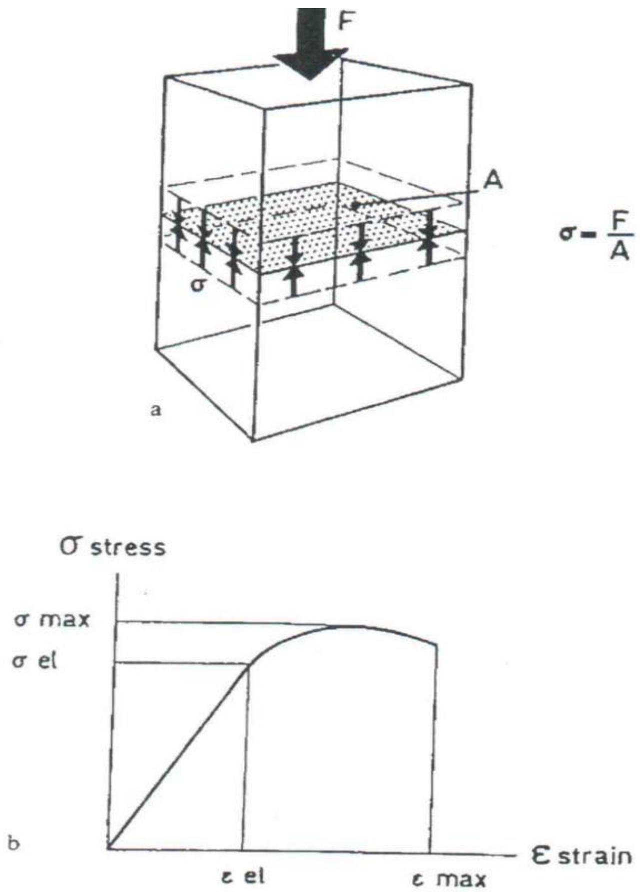
Fracture healing is a biological process, which results in healing of the bone injury as in other living tissues. Fracture of cancellous bone heals by creeping substitution. Fracture of cortical bone heals by two mechanisms. The first one is primary bone healing. Here there will be no evidence of callus formation. When there is direct across the fracture site, parallel to the long axis of the bone, by direct extension of osteons. This type of healing is known as contact healing. In small gaps of 150-200µm which are practically invisible, the cells form lamellar bone at right angles to the axis of the bone. This is followed by Haversian remodelling. This type of healing is known as gap healing.

In comminuted fractures where there are multiple fragments and large gaps, the union takes place by the formation of abundant callus. This type of healing is known as secondary bone healing.

Fundamental understanding of biological and mechanical aspects of fracture repair is important in selection of fracture management techniques. Two physical factors are important in understanding the mechanics of fracture healing. They are stress and strain.

STRESS :

Force (N) acting upon a material results in a state of internal stress. The unit of stress is force area i.e. N/m². This force deforms a material on which it acts



a An externally applied force (F) results in a deformation (δL) of a body and in an internal state of stress F/A (σ = force/area). The limit of failure can be described by strength as well as by strain (ε) (elongation at rupture). [7]

b The mechanical behavior of a given material can be characterized by a stress-strain diagram. The stress and strain interdependence is plotted. The limit of failure can be described by the strength (ε limit of stress σ_{max}) as well as by maximal deformation (ε_{max} = strain at rupture).

Figure 1. Stress – Strain curve

STRAIN

This represents a change in the length of a material by the acting force. This is percentage change of the original dimension. $\Sigma = \delta L/L$. Thus it is unit less. (refer ***Figure 1***)

These stress and strain determine stability (or) instability which ultimately determines bone healing. The degree of instability is best expressed as magnitude of strain. There should be a balance in strain. It should be adequate for mechanical induction of tissue differentiation and at the same time it should be below the critical level for that repair tissue. The critical level varies from tissue to tissue.

Elongation at rupture of different tissues

Granulation tissue 100%

Dense fibrous tissue 20%

Cartilage 20%

Cancellous bone 2%

Lamellar bone 2%

Strain characterizes the condition of deformation of the tissue elements taking into consideration the degree of displacement and the gap with ($\delta L/L$).

The deformation of the cells (or) tissues is critical. It depends on two factors viz. initial width of the fracture (L) and degree of displacement (δL) of the fragments.

For very small gaps (e.g.; less than 0.1mm), an imperceptible displacement (0.1mm) may results in verify high strain (i.e. > 100%). It may reach the critical level of strain tolerance of the cell. So a fracture with single narrow gap is very intolerant of even minute amounts of displacement. (refer ***Figure 2***)

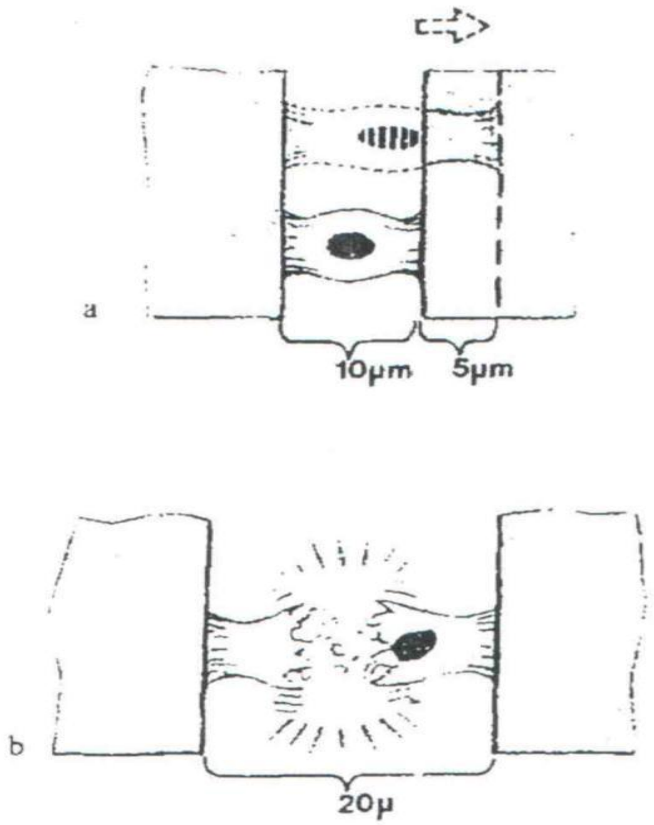


Figure 2. fracture gap in simple pattern of fractures

Strain of the individual tissue within the fracture site can be reduced by increasing the gap and /or by sharing the overall displacement by multiple serial gaps. This concept is evident in multifragmented comminuted fractures. Here there are large fracture gaps and the strain is distributed at the multiple fracture gaps and hence within the critical level, the produces mechanical induction of tissue differentiation by irritation. (refer figure 3)

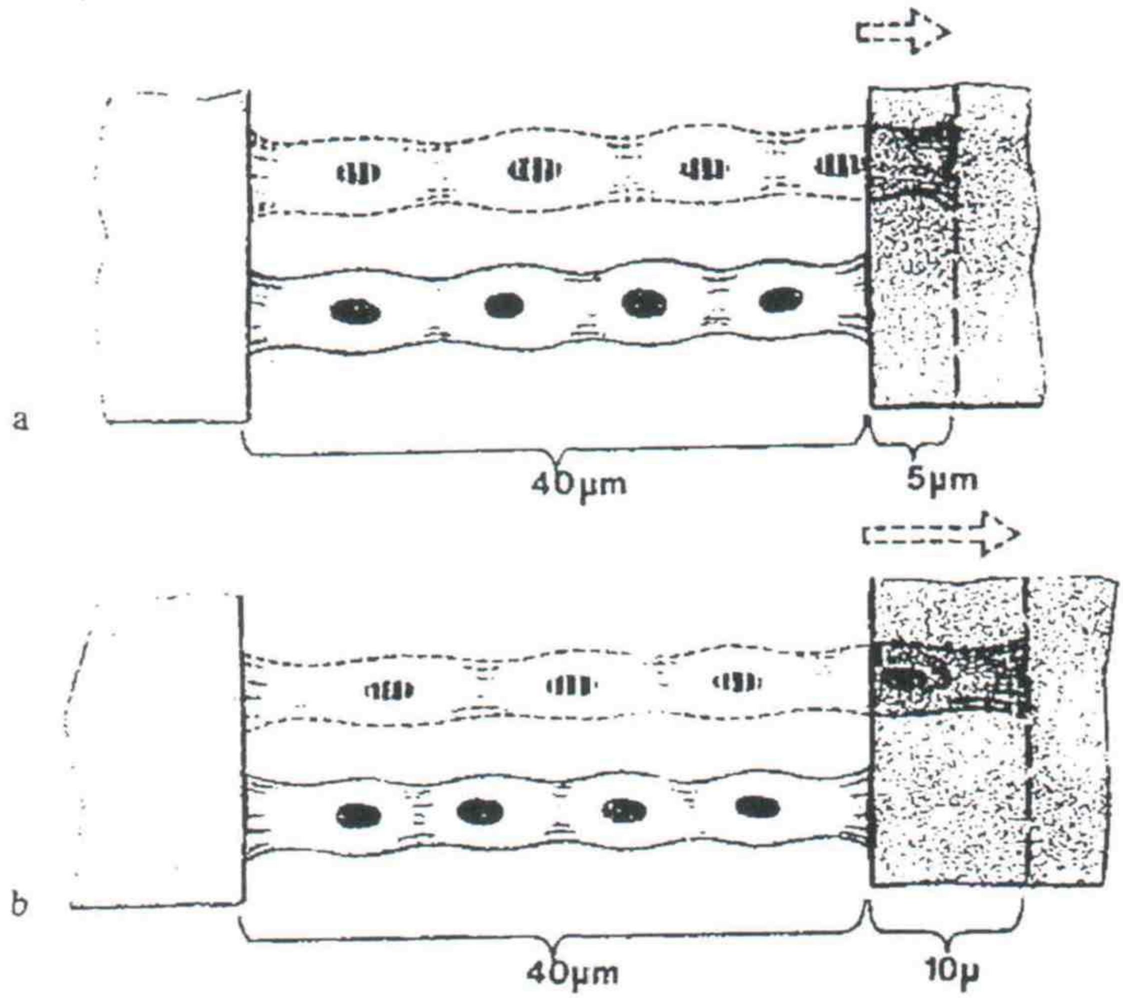


Figure 3. fracture gap in comminuted fractures

To put it simply, no gap and almost no strain produces primary bone healing which is seen in a simple fracture stabilized by rigid fixation.

Large gaps and low stain promote callus (or) secondary bone formation which is seen in complex fractures. Hence the reduction need not be precise i.e. anatomical in this situation. Because it is more tolerant to displacement as the strain is reduced due to larger gap width and serially located fracture gaps (Mast et al., 1989)

The union in comminuted fractures depends on the formation of bridging callus. This type of callus formation is particularly advantageous and can be explained biomechanically. The strength or stiffness of any structured depends on the product origin, Geometric factor and the strength or stiffness of the material within.

Strength of the material is directly proportional to the:

Geometric factor x stiffness of the material

If the geometric factor is large, even a weaker material can be strong. This is true in the case of bridging callus.

Cross sectional moment of inertia for a rod = Cross section area X square of distance from the central axis

$\pi /4 \times r2 \times r2 = \pi /4 \times r4$

Cross sectional moment of inertia for a tube (E.g. Bone) $\pi/4 \times (R4 - r4)$

The section modulus equal = CSMI /R

Strength of the bone in callus formation in comparison (refer to figure 4)

CSMI = π (R1 4 - r4) /4 CSMI = π (R2 4 - r4) /4 (Here r=0) {R2>R1}

(Intact bone) (In bridging Callus)

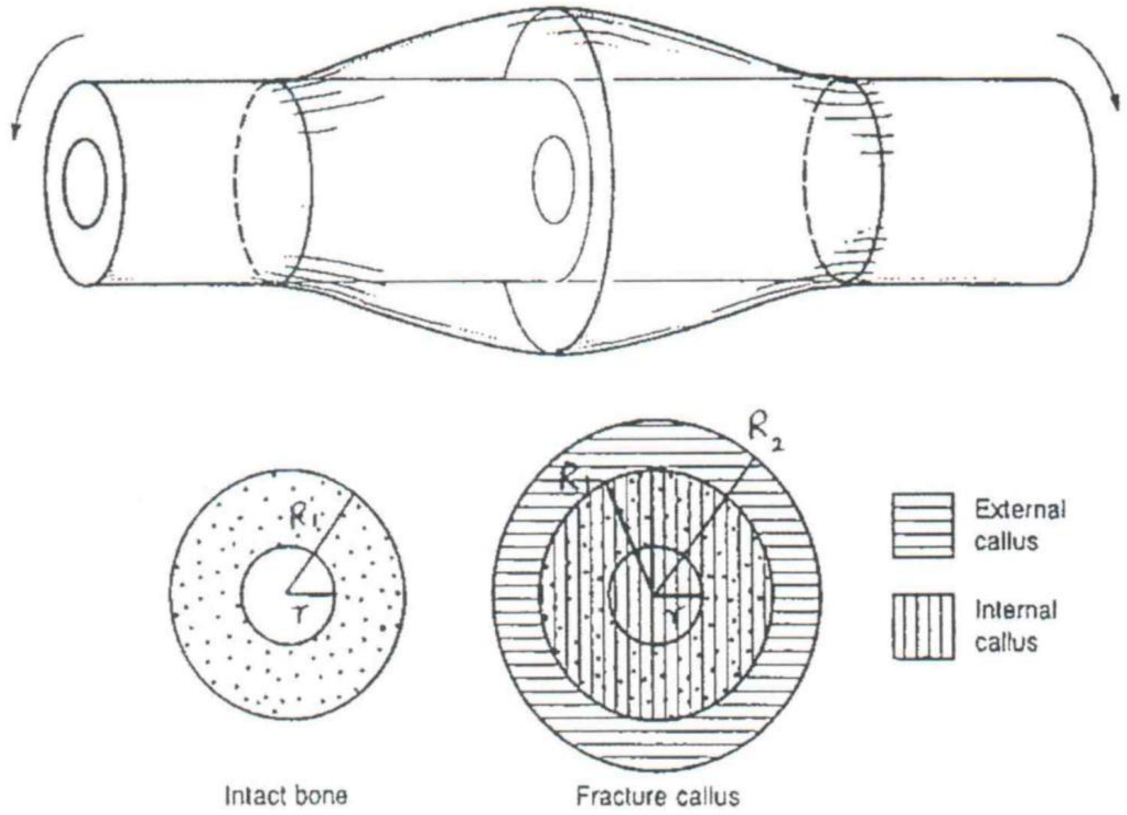


Figure 4. strength of bridging callus

Thus the bridging callus has the modulus of three times that of intact bone. This means the callus material needs to be only 1/3rd as strong as intact cortical bone to give the healing bone a normal strength. Thus the higher geometric factor compensates for mechanical weakness of the callus formation. The controlled micro motion produced by early rehabilitation helps in rapid formation of callus. This helps the patient to weight bear early when compared to the rigid fixation which results in much slower primary bone healing. Moreover rigid fixation has its own perils by violating the biology at the fracture site.

VARIABLES AFFECTING FRACTURE HEALING IN COMMINUTED FRACTURES

Comminuted fractures occur as a result of high violence. Hence they are associated with considerable damage to the soft tissue envelope due to dissipation of the energy, displacement and comminution of long fragments. Secondary to this, there is local disruption of blood supply which results in more necrotic tissues. This impedes new angiogenesis as well as decreases the viability of the mesenchymal cells. Because of the severe violence, this fracture may be of compound nature. This leads to even more necrosis and by predisposing to infection, it further increases the risk of non-union.

A unique type of comminuted fracture is segmental fracture. Here the medullary blood supply of the middle segment is entirely cut off. The viability of this middle segment is entirely dependent on periosteal and soft tissue envelope. If this envelope is damaged either by the initial violence or by the surgical technique the viability is greatly decreased. This is particularly true in tibial segmental fractures.

When the fracture gap is less, the amount of reparative tissue needed to fill the gap is less. But when the surrounding soft tissue is intact, lack of apposition may not compromise the healing potential of the fracture.

For the fracture healing to progress, some loading at the repair tissue should be present, because loading a fracture site stimulates bone formation. Controlled loading produces stress and strain, within the critical limits at the fracture site. As mentioned earlier, strain within critical limits induces early callus formation. For controlled loading to occur at the repair tissue, early mobilization is important. Early mobilization results in physiologic loading at the fracture site, increased vascularity, micro motion at fracture site all leading to fracture healing. Early rehabilitation also leads to improved joint function.

For controlled loading to occur without excessive motion at fracture site adequate fracture stabilization is important. Excessive loading and motion at the fracture site increase the risks of delayed union and non–union.

In many a situation, the comminuted fragments with intact soft tissue attachment serve as vascularised bone graft. Hence primary bone grafting is not needed. It may also violate the hematoma and intact soft tissue envelope at the fracture site.

To summarize, intact hematoma, periosteum and soft tissue envelope, fracture end apposition, controlled loading and adequate stabilization are the factors which promote fracture healing in comminuted fractures.

ROLE OF SOFT TISSUE IN THE PROCESS OF FRACTURE HEALING:

An ideal healing process for bone fractures requires harmony between optimal biology and optimal fixation(44). However fractures are mostly associated with a certain degree of soft tissue injury, which influences the treatment strategy of fractures and consequently their outcome. “Biological osteosynthesis” and “Less invasive surgery” emphasize the importance of adequate perfusion at fracture site and thus integrity of the surrounding tissues. With severe soft tissue trauma and apparent prominent oedema, conventional open approach to the fracture site with a wide dissection of soft tissues, including division of perforating vessels and exposure of the fracture zone, may lead to major complications like infection, prolonged fracture healing, non-union or a higher incidence of bone grafting(45). Some of the clinical studies also give evidence for early soft tissue coverage of such denuded fracture areas, especially in predisposed anatomical areas such as tibial shaft with benefits from plastic reconstructive procedures(46).

Between 1960 and 1980, several groups published and emphasized the importance and key role of soft tissue on fracture healing: the periosteum as well as the surrounding soft tissue(47). They were mainly focussed on preservation of the blood supply, the development of an extraosseous blood supply(48) and the cellular activity within the processes of osteogenic induction(49). With further research and the detection of the molecular interactions and pathway during the healing process, it became even more evident that it is necessary to protect and support the biological environment of fractures(50).

In summary, the role of the surrounding tissues on fracture healing is significant in the early stage as it is critical to the supply of cells and molecule to support the inflammatory stage.

CURRENT REVIEW

Management of unstable distal tibia fractures are an interesting challenge. The mechanism of injury and the prognosis of these fractures are different from pilon fractures, but their proximity to the ankle makes the surgical treatment more complicated than the treatment tibial midshaft fractures. Various treatment modalities have been suggested for these injuries, including conservative management, external fixation, intramedullary nailing, and plate fixation.

However, each of these treatment modalities is associated with certain advantages and disadvantages. Conservative management may be complicated by loss of reduction and subsequent malunion[(51)(52)]. Similarly, external fixation of distal tibia fractures may result in insufficient reduction, malunion, and pin tract infections[(53)]. Intramedullary nailing is considered the ‘‘gold standard’’ for the treatment of tibial midshaft fractures, but there are concerns about their use in distal tibia fractures. This is because of technical difficulties with a stable distal nail fixation (discrepancy between the narrow triangular diaphyseal diameter and wide circular metaphyseal diameter of the intramedullary canal) and the risk of propagating an existing distal tibia fracture into the ankle joint[(54)(55)]. Open reduction and internal plate fixation results in extensive soft tissue dissection/devitalisation and may be associated with wound complications and infections[(56)]. The optimal treatment of unstable distal tibia without articular involvement still remains controversial till date.

Studies of treatment outcome for strictly isolated distal tibia fractures of the metaphysis without any intrarticular component are uncommon.

Most studies are small case series and form the bulk of literature (level 4 evidence) and therefore treatment superiority for any one mode cannot be established. There is limited information on which to make evidence-based treatment recommendations for treatment of distal tibia fractures.

In 2002 S.M. Perren(16) stated that the risk of disrupting blood supply is increased with the classical ORIF approach in the metaphyseal region of the tibia. Even if MIPO is technically more demanding and requires a higher exposure to radiation because of closed indirect reduction, it has a biological advantage over ORIF, especially when dealing with critical soft tissue conditions.

OUTCOME STUDIES OF MIPO IN DISTAL TIBIA FRACTURES :

In 1997, Helfet et al[23]were one of the **first to introduce MIPO** in distal tibia fractures. They treated the fracture in 2 stages. In the first stage they fixed the fibular fracture, if present, and applied an external fixator to the tibia. In the second stage they did a limited ORIF of the pilon fracture, and introduced subcutaneously a **semitubular plate** that they contoured manually to the shape of the distal tibia. They applied this protocol to 20 patients with 8 intra-articular and 12 open extra-articular distal tibial fractures. All their fractures united. Two fractures healed with more than 5º varus alignment and 2 fractures healed with more than l0º recurvatum. None of the patients had deep infection. The average range of motion in the ankle for dorsiflexion was 14º and plantar flexion averaged 42º.They concluded that with a longer follow up and larger number of patients, MIPO will be a good option keeping in mind the low incidence of complications.

Hazarika et al[41] treated 20 patients who had open and closed distal tibia fractures with minimally invasive locking plate osteosynthesis (MILPO). Thirteen of their patients had **preliminary external fixation** for a prolonged period. Average time to full weight bearing was 18.1 weeks (closed fractures), and 19.3 weeks (open fractures). Two fractures (1 open and 1 closed) who had temporary external fixation were **bone grafted from the iliac crest** during the definitive MILPO procedure. They had two cases of wound breakdown and one case of each wound infection, implant failure, and reflex sympathetic dystrophy. However, their study did not comment on the functional results of the patients.

Borg et al [57] treated closed distal tibia fractures in 21 patients with titanium L.C.P. and reported fracture healing in 17 patients within 6 months. There were 2 cases of non-union and delayed union each along with 2 cases of deep infection and 4 malunions. 2 patients had to be re-operated due to initial fracture malreduction.

Hasenboehler et al[42] did a retrospective study of 32 patients who underwent MIPO with L.C.P. and found that **prolonged healing was observed in simple fracture patterns** which were treated with bridge plating. 27 patients healed at 9 months with his criteria for radiological union being callus at any one cortex, both anteroposterior and lateral views.

Redfern et al [39] studied 20 patients who were treated by MIPO for **closed fractures** of their distal metaphyseal tibia and found bony union in all patients with a mean period of 23 weeks (range: 18–29 weeks), without need for further surgery.

There was one malunion, but no cases of deep infections or failures of fixation.

Lueng and law et al[59] did a retrospective study on **62 patients** who underwent MIPO with LCP for their distal tibial fractures (both extra and intra-articular) and reported satisfactory ankle scores with a **mean time of bony union of around 19.5 weeks**.

Ronga et al (2010) [60] studied effectiveness of MIPO in distal tibia fractures among 19 patient retrospectively with a minimum of 2 years follow up and reported that though union was achieved in all but 1 patient, the level of **physical activity was permanently reduced in most patients**.

Collinge et al[61] studied 26 patients who **underwent MIPO in high energy** metaphyseal distal tibia fractures and found the mean fracture healing time was 35 weeks (12–112 weeks) with acceptable alignment in all but 1 case. Two patients (7%) had loss of fixation and 9 **(35%) underwent secondary surgeries** to achieve union. **Risk factors for healing problems included high grades of fracture comminution, bone loss, and high-grade open injuries**.

Some of the above and other MIPO studies are condensed in table below:

AUTHOR	NO. OF CASES	TECHNIQUE	OUTCOMES
Gao et al.	32 distal tibia (17 extra-articular, 9 open)	21 MIPO – polyaxial medial locking plate 11 ORIF – polyaxial medial locking plate	Mean time to union–13 weeks (MIPO)
Lau et al.(51)	48 distal tibia (43 extra-articular, 9 open)	MIPO – precontoured LCP	Mean time to union – 18.7 weeks 1 acute infection (open fracture) 7 late infection (5 closed, 2 open) 5 delayed union 25 metalwork removal (mainly for irritation)
Collinge et al.(38)	26 high-energy extrarticular or simple intra-articular distal tibia fractures	MIPO – precontoured LCP or DCP	Mean time to union – 35 weeks 1 malunion 5 infection 9 patients required procedures for

			delayed/non-union
Bahari et al.	42 distal tibia and pilon (8 open, 15 extra-articular)	MIPO – precontoured LCP	Mean time to union – 22.4 weeks 1 deep and 2 superficial infection
Pai et al.	23 closed distal tibia	MIPO – precontoured DCP	Mean time to union – 19.5 weeks 1 superficial infection 1 revision due to fixation failure
Hazarika et al.	20 distal tibia (8 open)	MIPO – LCP	Mean time to full weight bearing – 18.1 weeks (closed) 19.3 weeks (open) 2 non-union (both open fractures) 3 wound infection/breakdown (all closed fractures) 1 implant failure 3 removal of metalwork
Krackhardt et al.	69 distal tibial fractures (41 extra-articular)	MIPO – LC-DCP	1 malunion 1 revision due to instability 3 cases of infection 5 delayed union requiring bone grafting
Redfern et al.	20 distal tibia (extra-articular)	MIPO – precontoured DCP	Mean time to union – 23 weeks 1 malunion 1 superficial infection 3 cases of metalwork irritation 1 screw impingement on distal tibia–fibula joint 1 complex regional pain syndrome
Maffulli et al.	20 distal tibia (15 extra-articular)	MIPO – 1/3 tubular, cloverleaf or DCP	7 malunion (angular deformity of 7–108) 1 non-union requiring bone grafting 1 screw breakage requiring re-operation
Borg et al.	21 distal tibia (extra-articular)	MIPO – LC-DCP	2 non-union 2 delayed union 2 deep infection 4 malunions 2 re-operations due to malreduction
Oh et al.	24 tibial fracture (12 distal tibia)	MIPO – LC-DCP	Mean time to union – 13.7 weeks (for distal fractures) No complications amongst distal tibial

			fractures
Oh et al.	21 distal tibia	MIPO – LC-DCP	Mean time to union – 15.2 weeks 1 rotational malunion
Khoury et al.	24 distal tibia (4 open)	MIPO – DCP	Mean time to union – 12.3 weeks 2 malunion 1 superficial infection
Helfet et al.	20 distal tibia (12 extra-articular, 2 open)	MIPO – semitubular plate	Mean time to full weight bearing – 10.7 weeks 4 malunion
Ronga M et al.	19	MIPO	Union: 18 (22.3 wks, range 12-24) Nonunion:1 No malunion (≥7° deformity or ≥1 cm LLD) Deep infection:3
Ahmad MA et al.	18	MIPO	Union: 15 (21.2 wks) Delayed union: 3 Superficial wound infarction: 1 Chronic wound infection: 1 Implant failure: 1
Hasenbohehler E et al.	32 (open fracture: 8)	MIPO	Union: 29 (27.7 wks, range 24–60) Nonunion: 2 No malunion (≥ 5° deformity or ≥ 1 cm LLD) Plate bending (18°): 1 Pseudoarthrosis: 2
Hazarika S et al.	20 (open fracture: 8)	MIPO	Union: 18 (28.5 wks, range, 9–68) Nonunion: 2 Delayed wound break down: 2 Wound infection: 1 Implant failure: 1 Secondary procedure: 2
Bahari S et al.	42 (open fracture: 8)	MIPO	Union: 42 (22.4 wks) No malunion Superficial wound infection: 2 Deep infection: 1 Implant failure: 1
Collinge C et al.	38 (open fracture: 8)	MIPO	Union: 38 (21 wks, range 9–48) Malunion (≥ 5° deformity) : 1 Secondary procedure: 3
Mushtaq A et al.	21 (open fracture: 4)	MIPO	Union: 21(5.5 months, range 3–13) Delayed union: 1 Non union :1 Wound infection: 2

			Secondary procedure: 2
Lau TW et al.	48 (open fracture: 9)	MIPO	Delayed union: 5 Wound infection: 8 Secondary procedure:1
Gupta RK et al.	80 (open fracture:19)	MIPO : 71, Open: 9	Union: 77 (19 wks, range 16-32) Delayed union :7 Non union: 3 Malunion (≥ 5° deformity or ≥ 1 cm LLD): 2 Wound infection:1 Wound breakdown: 2 Secondary procedure: 2
Srestha et al	20	MIPO	Union: 20 (18.5 wks, range 14-28) Delayed union :1 No malunion (≥ 5° deformity or ≥ 1 cm LLD) Superficial wound infection: 2 Deep infection: 1 Secondary procedure: 1
Present Study	26	MIPO	Union: 6.06 months ± 1.7 Malunion: 0 Infection: 2 Non-union: 0

Table 1. *MIPO studies*

COMPARISION OF MIPO WITH OTHER TECHNIQUES:

In a retrospective study, Cheng et al [(63)] compared minimally invasive plate osteosynthesis with plate fixation and demonstrated a significantly higher incidence of hardware irritation complaints among patients treated with minimally invasive plating than in those treated with the conventional open reduction and internal fixation (9 of 28 Vs 2 of 30; P = 0.008). There was no significant difference in healing time or functional result between the two techniques though.

A systematic review of plate fixation versus intramedullary nailing for displaced extra-articular distal tibia(defined as 4cm to 11cm from the tibial plafond) fractures from Jan 1965 to July 2012 done by Li and Yang et al (2013)[(62)] revealed that only 8 studies were significant. Most of the studies were retrospective or large case series. Out of a total of 424 fractures, 207 patients underwent intramedullary nailing and 217 patients underwent plate fixation.

The total complication rate for intramedullary nailing was significant higher as compared with plate fixation {44.5 vs. 25.8 % [statistically significant]}. The incidence of malunion was more common in intramedullary nailing than in plate fixation {20.1 vs. 4.5 % [statistically significant]}. Meanwhile, significantly less wound problems happened in intramedullary nailing than in plate fixation {2.9 vs. 7.5 % [statistically insignificant]}. In addition, locking plate fixation with mini-invasive technique tended to have a lower complication rate than conventional plate fixation, although the difference was not significant (21 vs. 28.4 %).

They concluded that plate fixation; especially MIPO technique should be preferred for extra-articular distal tibia fractures because of its low complication rate, whereas in fractures with serious soft tissue injuries, intramedullary fixation should take priority.

In a diagonally opposite prospective randomized study of 85 distal tibia fractures managed with either IM nailing or minimally invasive plate osteosynthesis (44 nailed, 41 plated), Guo et al[(64)] found that all fractures united with no statistically significant difference in pain, function, or alignment based on American Orthopaedic Foot and Ankle Society scores. Their study had stricter inclusion criteria (purely extra articular and closed fractures).Co morbid conditions of patients relevant to fracture healing were excluded. Patients were also excluded if they required fibular plating. They found a wound complication rate of 14.6% in MIPO as compared to 6.8% in the IM nailing group.

A systematic review of 1125 non articular distal tibia fractures (from 1975 to 2005) done by Boris et al in 2006 [(56)] revealed that only 16 studies were significant. Most of the studies were retrospective or large case series. 521 patients were treated conservatively, 489 patients underwent intramedullary nailing, and 115 patients underwent internal plate fixation. 12.4% of the fractures were open.

In the group managed conservatively, non-union rate was 1.3%, malunion rate was 15%, and 4.3% required secondary surgical procedures. In the group managed with IM nailing the nonunion rate was 5.5%, infection rate was 4.3%, malunion rate was 16.2%, and 16.4% of the patients required secondary surgical procedures. In the Plate fixation group, nonunion rate was 5.2%, infection rate was 2.6%, malunion rate of 13.1%, and 8.7% required a secondary surgical procedure.

Their final conclusions were :

- Non union and malunion appeared more frequently in the IM nailing group than in the plating group.

- The risk of infection trended lower in the plating group (2.6%) Vs (4.3%) IM nailing group [difference not statistically significant]

They however did not have many patients treated with MIPO plating.

COMPLICATIONS OF MIPO :

Pierre Joveniaux & Xavier Ohl et al studied the management and complications of Distal tibia fractures in 101 cases(65) and stated that surgical complications occurred in 30 patients (30%). **Nonunion was found in 35% of comminuted fractures** ($p<0.001$), in **38% of open fractures** (against 8% closed fractures and $p<0.007$) and in 29% of cases of external fixation (against 6% for other treatments and $p<0.003$).

Lau et al(58) evaluated the clinical outcome of 48 cases of MIPO with special attention to infection rates and found a **15% incidence of late infections**. The presence of late infection had no obvious effect on the time to bony union. **52% had implant removal** and the most common reason was skin impingement by the implant.

To conclude, MIPO seems to be having less malalignments but a greater number of implant / hardware related problems. Nailing on the other hand seems to be having a higher malunion rates.

Materials and Methods

From January 2008 to December 2011 the Ortho 3 unit of Christian Medical College and Hospital, Vellore, South India, treated 107 distal tibia fractures(both open and closed).46 patients underwent IM nailing , 24 patients underwent conventional open reduction and internal fixation with plate fixation and 37 underwent percutaneous plating with MIPO technique.

All consecutive 37 patients who were treated by minimally invasive plate osteosynthesis for their extra articular distal thirds tibial fracture in this period were included. The criteria for inclusion in our study were (1) All distal thirds extra articular tibial fractures treated with MIPO (AO type A1,A2 & A3 only) {Distal third will range from 11 cm to 1 cm above the ankle joint}(66)with or without concurrent fibula fractures (AO type A1,B1,C1,C2,C3 only) , (2) both open and closed fractures , (3) available follow up results in terms of 24 months or more; and (4) informed consent from the patient to take part in the study.

Our exclusion criteria included: Stress fractures, Paediatric age group fractures, Pathological fractures/metabolic bone diseases and distal tibia fractures with intra-articular involvement (Pilon fractures)

We excluded 3 patients with pathological fractures and 2 patients in the paediatric age group (less than 15 years).

These exclusions left 32 patients, who were included in this retrospective study.

The hospital numbers of these patients were retrieved from the operation theatre register. All these patients were then contacted by Email / phone or posts and asked to come for a follow up in OPD. Five patients were lost to follow up and could not be traced even on a house visit. One patient who had followed up for the initial 1 year after the trauma and surgical treatment, died of stroke related complications.

Finally 26 patients were included in our study.

Consent was obtained from the respective patients and a detailed clinical assessment was done by the two examiners independently followed by specific functional scores and measurement of radiograph parameters.

Outcome measurement

The functional outcome was measured by using standard questionnaires and consisted of the AOFAS & OLERUD and MOLANDER Scores.

The American Orthopaedic Foot and Ankle Society Score **(AOFAS)** introduced in 1994 by Kitaoka et al(67) and has nine questions related to three components:

Pain (1 Question with 40 points), Function (7 Questions with 50 points) and Alignment (1 Question with 10 points) leading to a total possible score of 100 points. The questions related to alignment and range of motion (measured by an orthopaedic goniometer) was completed by the examiner based upon clinical assessment and radiographs; the other questions were completed by the individual patients. The individual scores were then added together to obtain an overall functional score, which then was expressed as a percentage of the normal (100 points).

The **Olerud and Molander Score**(68) is a self administered patient questionnaire with a score of 0 (Totally impaired) to 100 (Completely impaired) and is based on nine different items: Pain, Stiffness, Swelling, Stair Climbing, Running, Jumping, Squatting, Supports and

Work/Activities of daily living. Scores of 91-100 were graded as excellent, 61-90 as good, 31-60 as fair and 0-30 as poor results.

Radiographic assessment was done comparing the ateroposterior and lateral views of the affected and the normal leg with both the knee and ankle joints included.

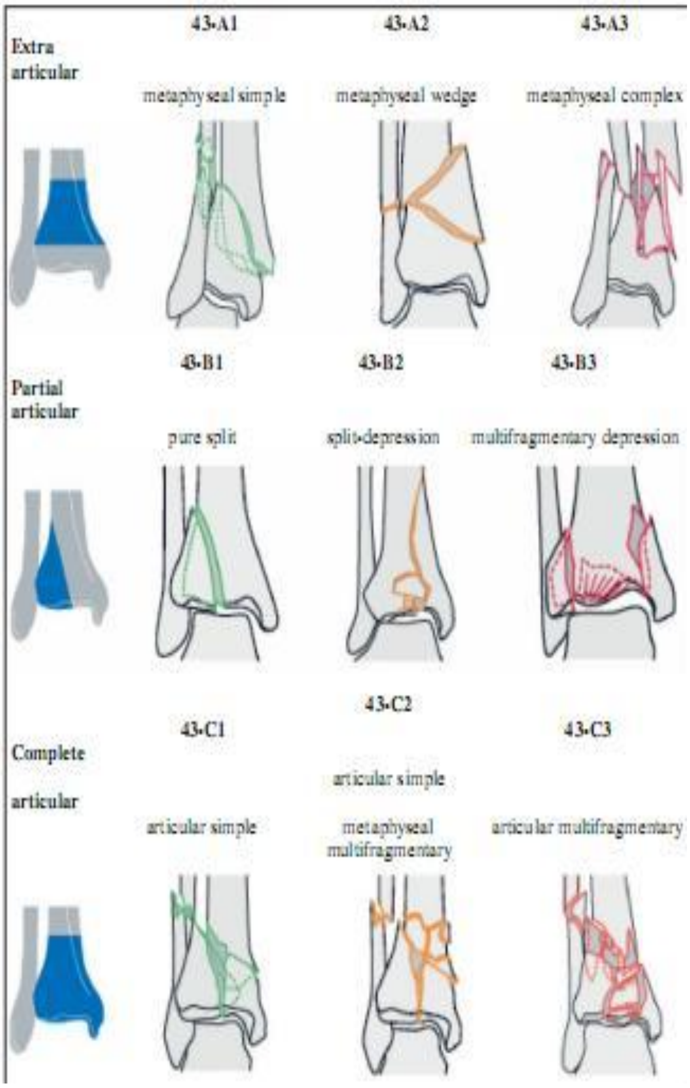


Figure 5. *AO classification system, type 43 – distal tibial fractures*

If fracture union was not achieved by the sixth month after surgery, the situation was graded as delayed union and by the ninth month as nonunion. We assessed deformities in sagittal and frontal planes and shortening on standard long-leg radiographs. The joint orientation angles were used to access axial deviation in frontal and sagittal planes (lateral distal tibial angle 89 ± 3 , anterior distal tibial angle 79.8 ± 1.6 degrees)[69]

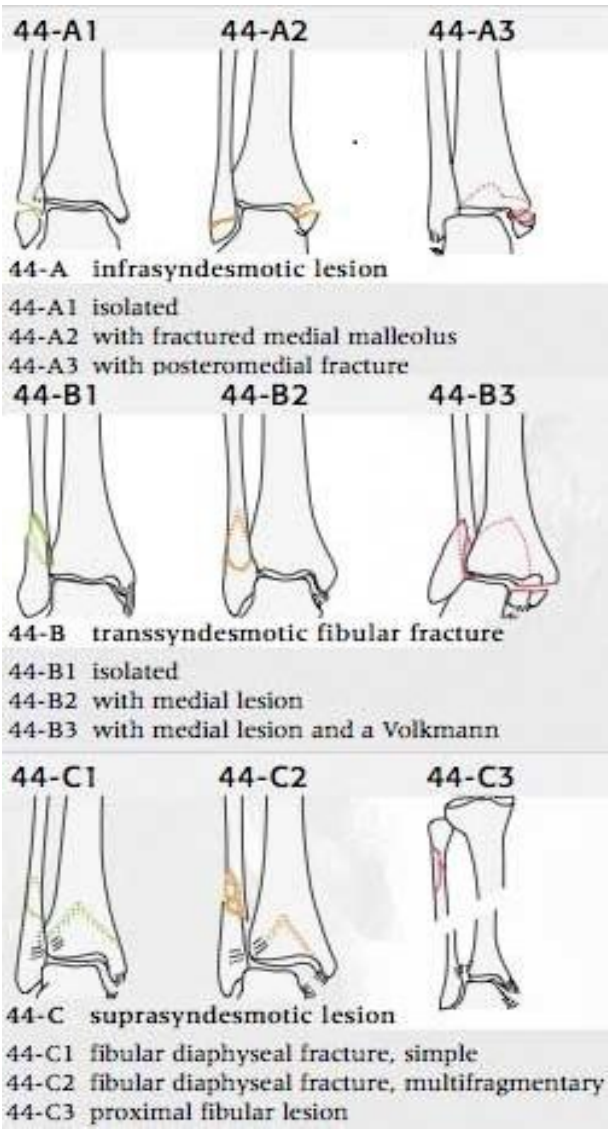


Figure6. *AO classification system – distal fibula fractures*

Malunion (more than 5 degrees of varus & valgus angulation, more than 10 degrees of Anteroposterior angulation), shortening (more than 10mm – significant)[70] and the time to radiographic union (callus on three out of four cortices). Change of alignment from immediate postoperative period till final follow up was also documented.

All major and minor **complications** were documented at follow up.

Surgical technique : Surgical procedures were performed by a senior consultant in 5 cases, junior consultant in 19 cases and a post graduate registrar in 2 cases. In all cases surgery was performed in supine position with the use of an image intensifier. Fracture reduction was achieved manually in all but 2 cases where a femoral distractor was used. A curvilinear incision of 3 to 4cms was made at the medial end of distal tibial metaphysis protecting the saphenous vein. A subcutaneous or extra periosteal tunnel was prepared with the use of a periosteal elevator for subsequent plate insertion. After insertion of the implant, the position of the bone fragments and the plate was checked with an image intensifier. One screw was inserted in each of the main fragments and the position of the fracture and plate were checked again. Fixation was then completed with the insertion of a planned number of screws (a minimum of 3 to 4, 3.5 mm locked screws on either side of the fracture were considered sufficient. The different plates used were L.C.P. in 22 cases and D.C.P. in 3 cases. Concurrent fibula fracture fixation with a precontoured D.C.P. was done in 18 cases. After fracture fixation was complete and final radiological evaluation of all components of fixation performed, the wounds were closed in layers.

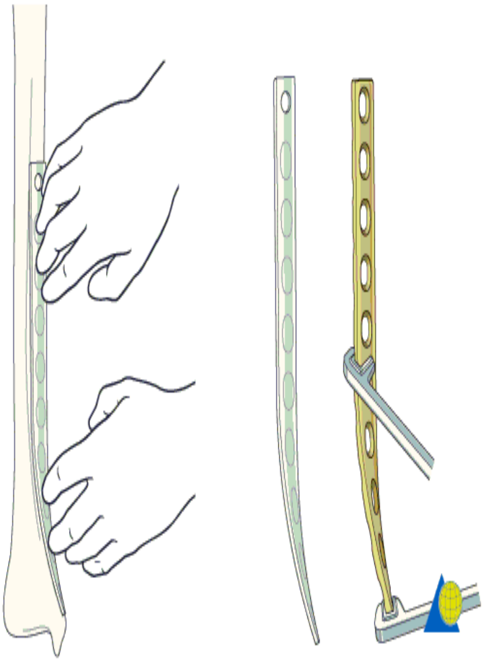


Figure 7. *Pre bending of the plate*

Figure 8. *Distractor used to reduce fracture*

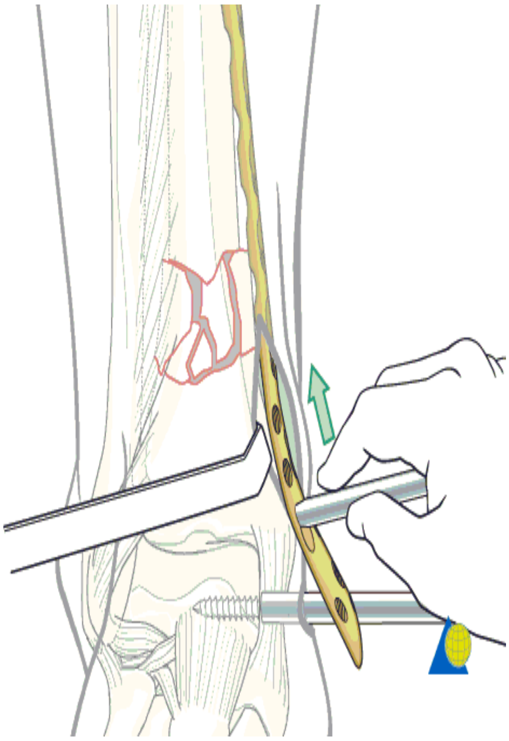


Figure 9. *Sliding of plate through sub-cutaneous tunnel*

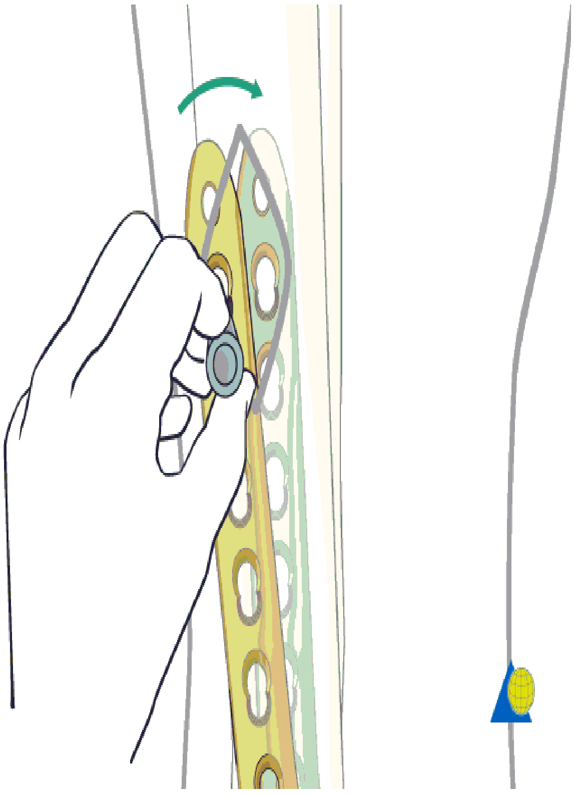


Figure 10. *Positioning of the plate after fracture reduction*

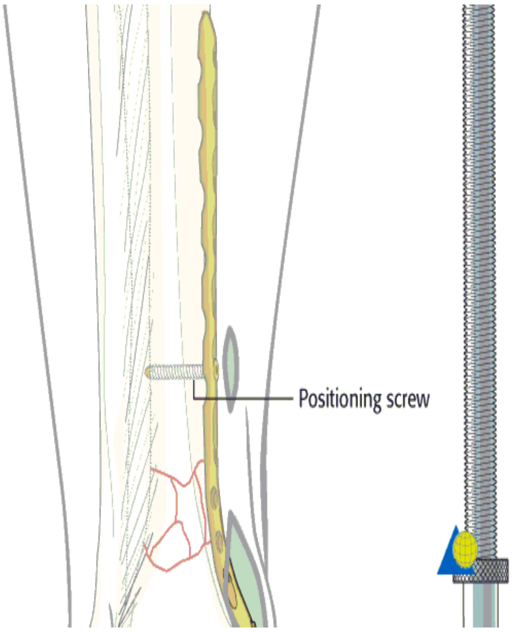


Figure 11. *Applying of positioning screw*

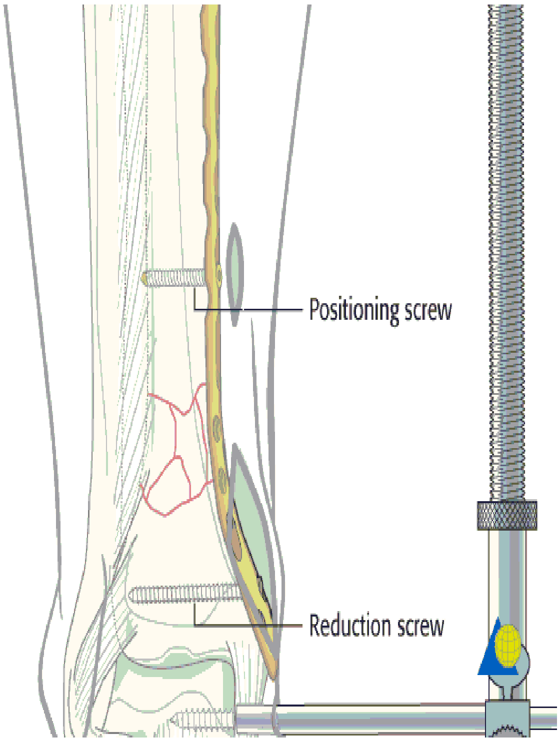


Figure 12. *Applying of reduction screw*

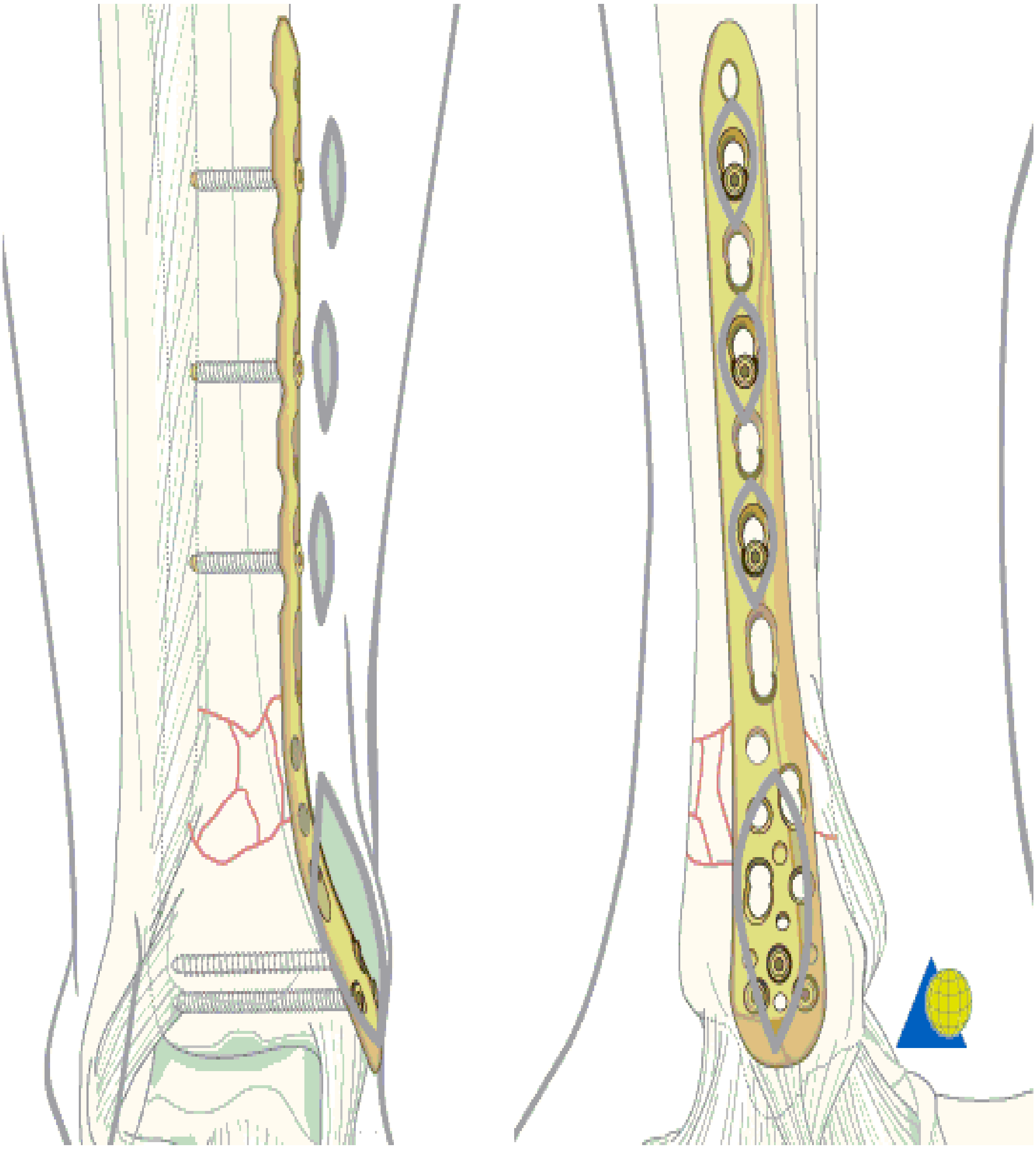


Figure 13. *MIPO of distal tibia with L.C.P.*

Antibiotic prophylaxis in the perioperative period consisted of intravenous Cloxacillin and Gentamycin for closed fractures. Intravenous Crystalline Penicillin was added if it was an open fracture. All intravenous antibiotics were continued for a maximum of 2 days in case of closed fractures and 5 days in case of open fractures.

The patients were discharged from the hospital once the wounds looked healthy and were asked to ambulate with a pair of crutches (non weight bearing) and were followed up at regular intervals in the OPD. Progressive weight bearing was advised depending on fracture union.

Statistical Analysis: The final data was then be analyzed for significant relationships among the studied variables with the help of statistical analysis Descriptive statistics were given using frequencies with percentages or mean with standard deviation. To compare the functional scores among the groups Independent T test and ANOVA was used. Correlation between the scores were computed either using Person correlation or spearman's correlation depending on the data normality.The scatter plots were given for the visual representation of data. All the statistical analysis were done using STATA/IC 10.1 version. (done with STATA 10.0 I/C software for windows).

Results

26 patients who underwent minimally invasive plate osteosynthesis of their distal tibial extra articular fractures were analysed.

Mean age of patients at the time of injury was 42.5 ± 13.12 years (range : 21 to 74 years) ; there were 18 male and 8 female patients. The minimum follow up period was 24 months (mean of 32.7 months; range: 24 to 70 months).

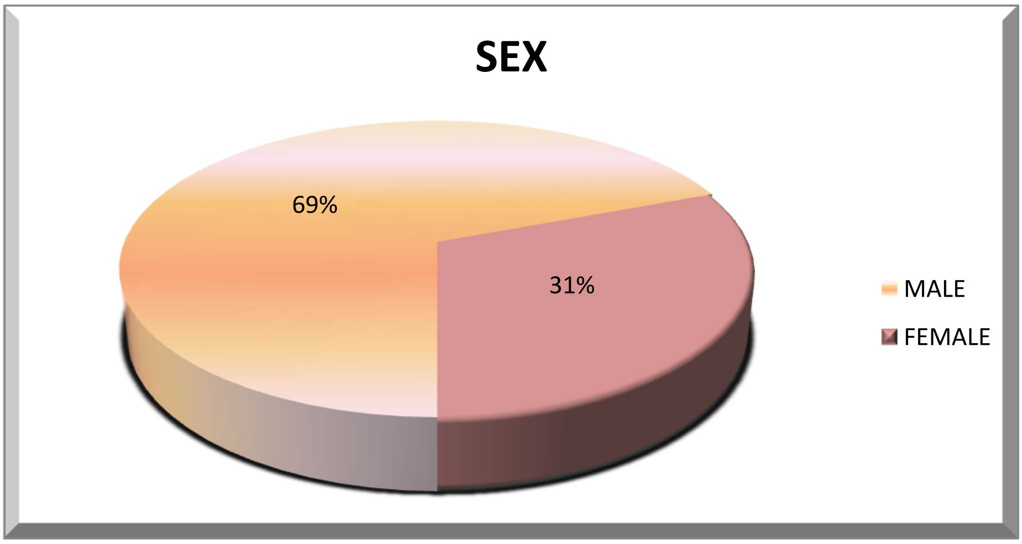


Diagram 1. *Pie Chart showing distribution of sex*

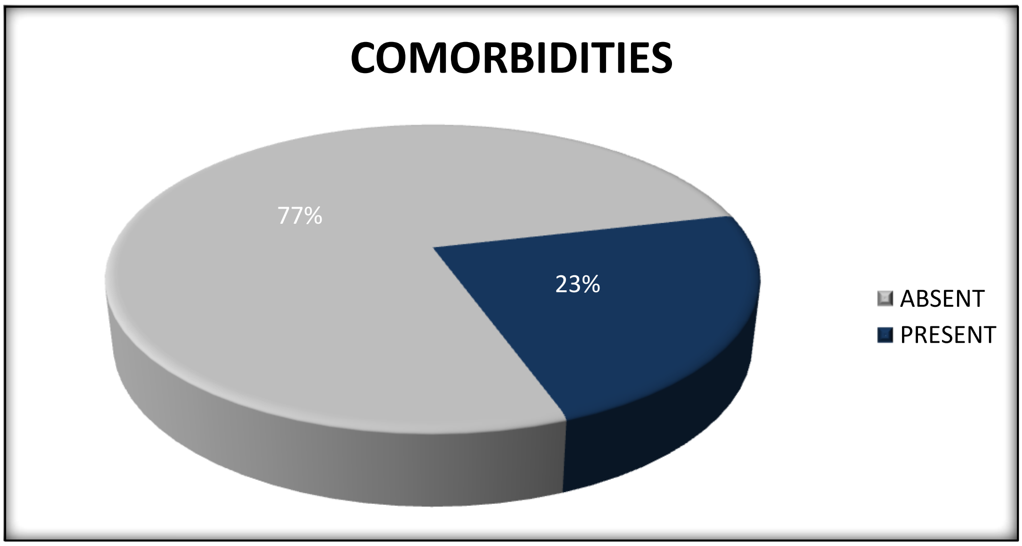


Diagram 2. *Pie Chart showing distribution of comorbidities*

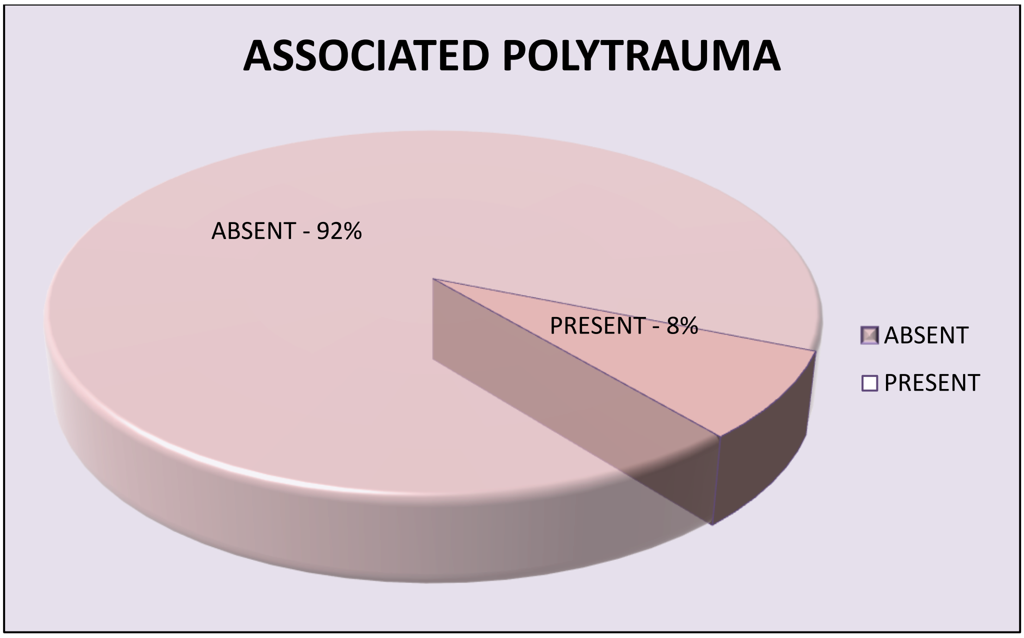


Diagram 3. *Pie Chart showing distribution of associated polytrauma*

Isolated lower leg injuries were seen in 16 patients and another 10 had additional injuries/fractures of other segments.

In the 26 patients, 24 patients had high energy injuries (23 had road traffic accidents and 1 patient had fall from a height of 15 feet) and 2 patients had low energy injuries (both had twist and fall from a chair).

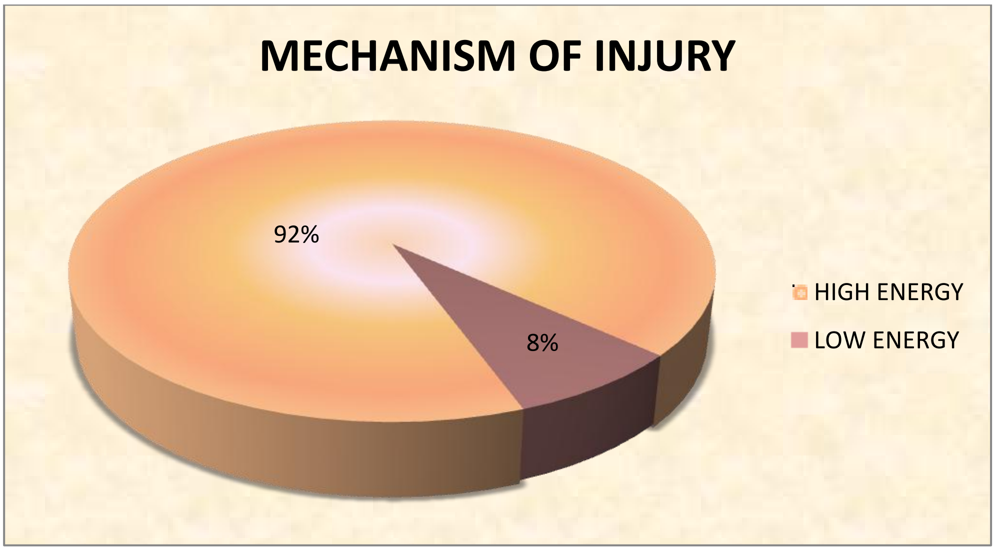


Diagram 4. *Pie Chart showing distribution of mechanism of injury*

Fracture distribution according to AO-Muller classification is shown (figure 5). Most fractures were of A2 pattern. The average distance of the fracture was 5.88cms from the tibial plafond (range : 2.4 to 10.9 cms). In most, the center of fracture was at the level of metadiaphyseal junction.

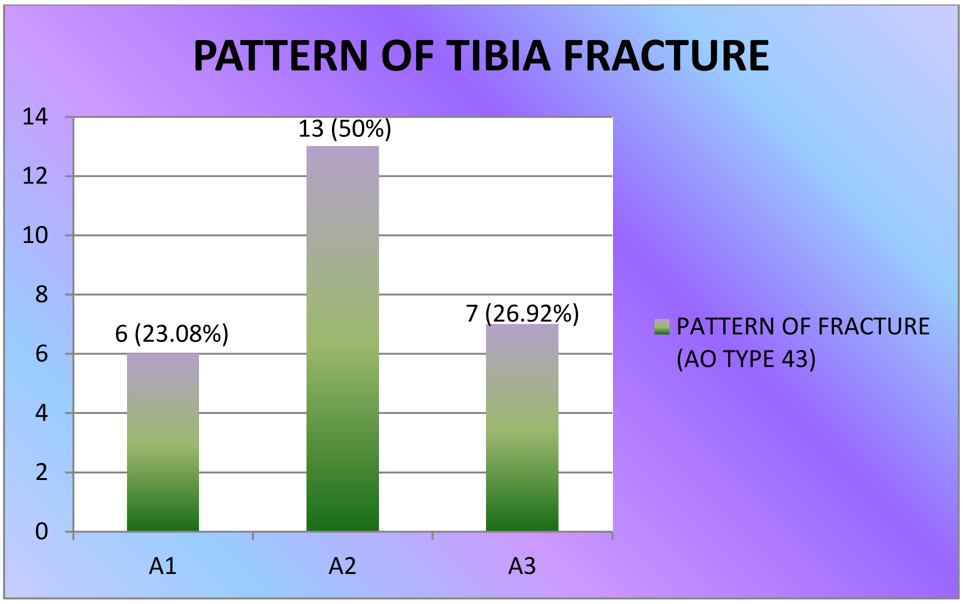


Diagram 5. *Bar Diagram showing distribution of pattern of fracture*

Open fractures were seen in 10 patients and included Gustilo and Andersen type I fractures in two patients; Type II in two; Type IIIA in four; and Type IIIB in two patients. Closed soft tissue injuries were seen in 2 patients (Tscherne grade I in one patient and Tscherne grade II in one patient). The remaining patients had no major soft tissue injuries.

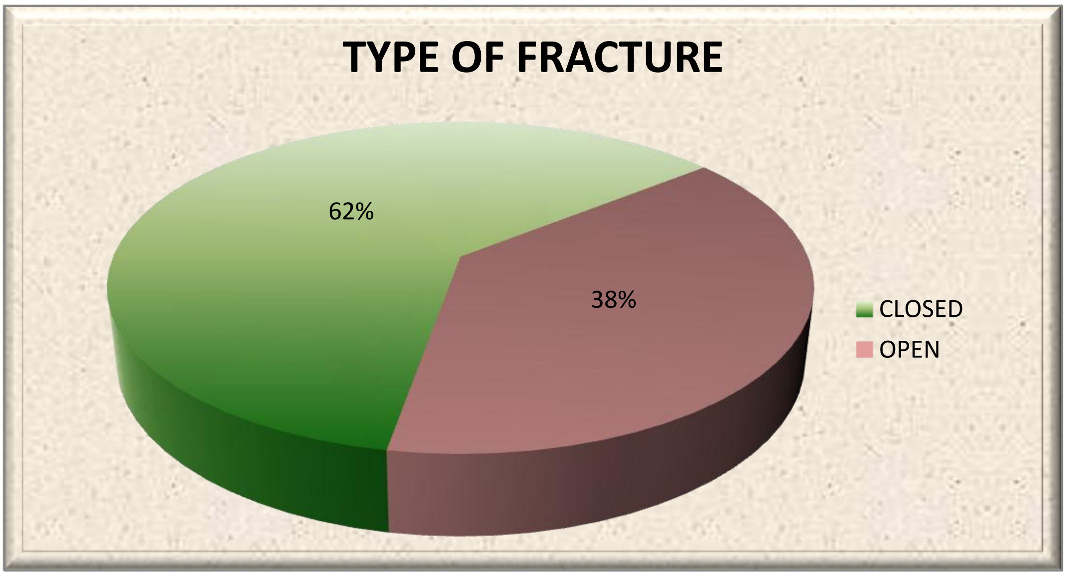


Diagram 6. *Pie Chart showing distribution of type of fracture*

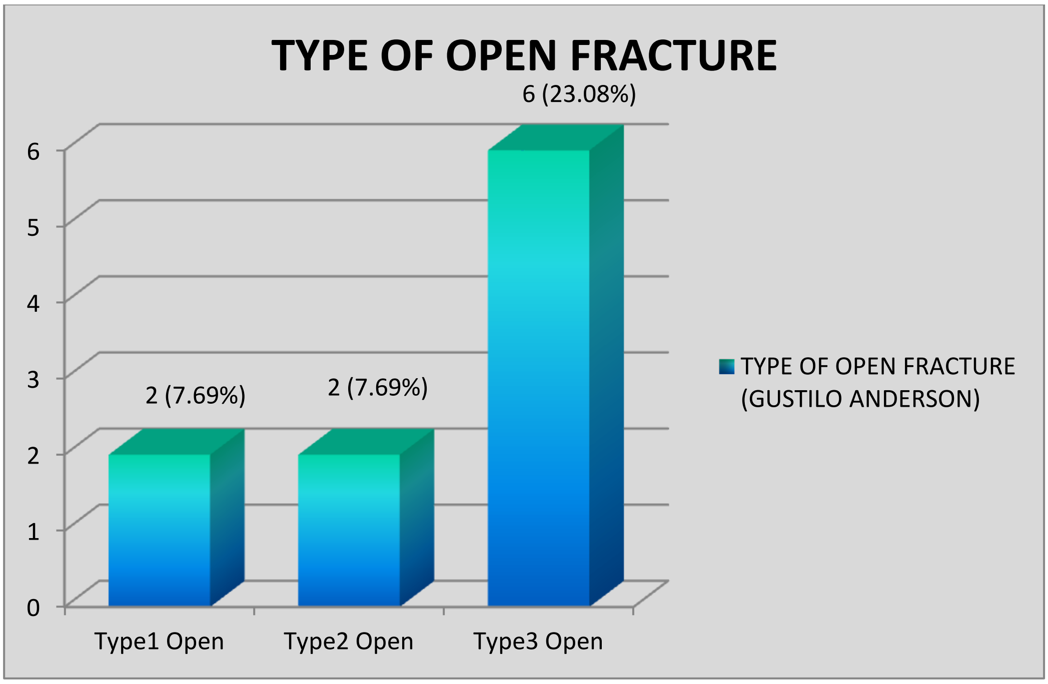


Diagram 7. *Bar Diagram showing distribution of type of open fracture*

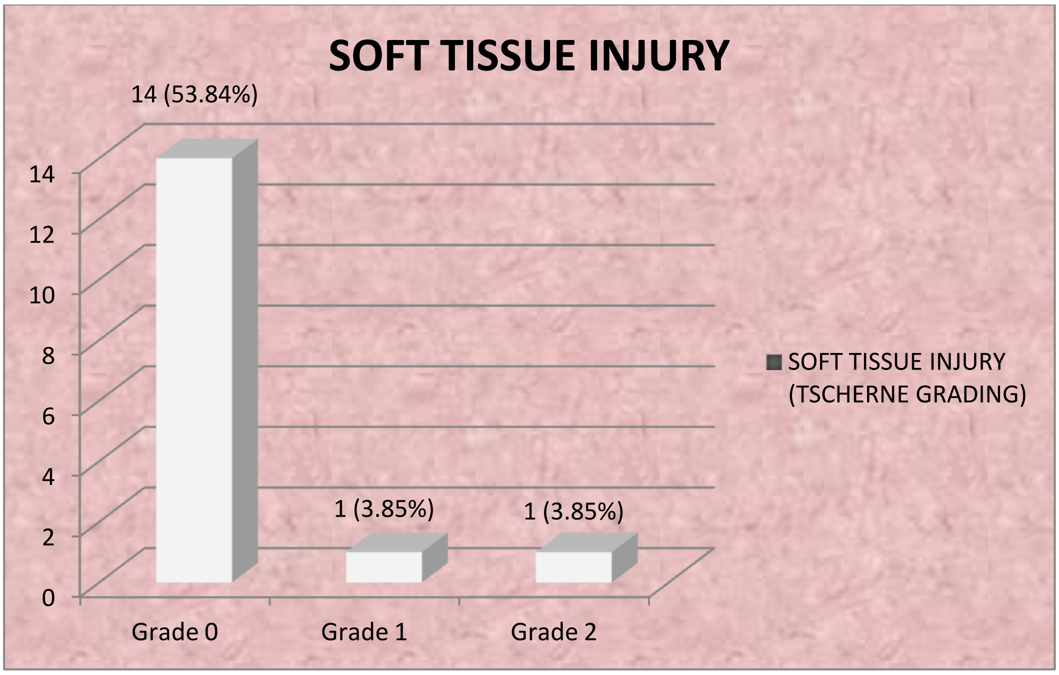


Diagram 8. *Bar Diagram showing distribution of soft tissue injury*

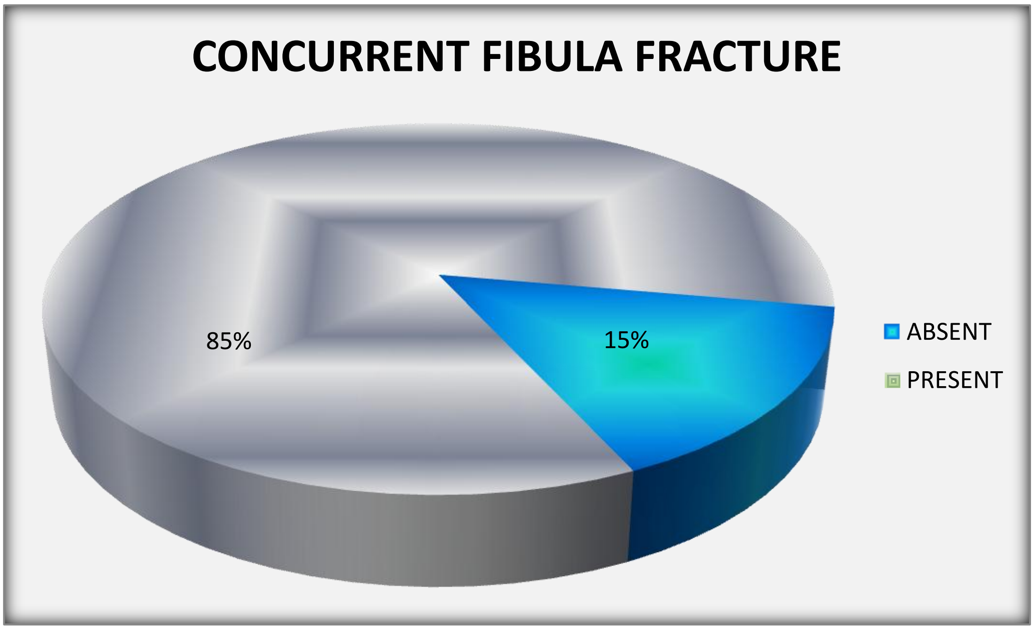


Diagram 9. *Pie Chart showing distribution of concurrent fibula fracture*

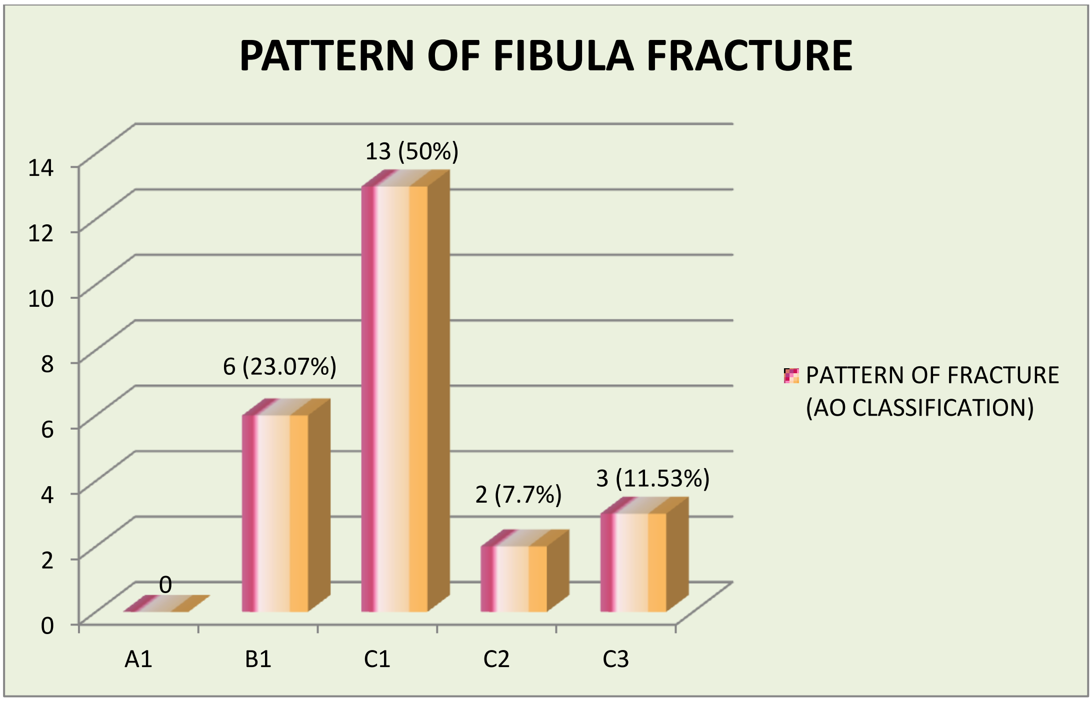


Diagram 10. *Bar Diagram showing distribution of pattern of fibula fracture*

The mean interval between injury and definitive surgery was 7.92 ± 23 days (range: 1 to 120 days).One patient had underwent native splinting elsewhere and had presented to us 4 months post injury. If we consider him as an outlier then our time to definitive surgery would become 3.44 days.

The average hospital stay for all patients was 10.2 days and was slightly less for patients with closed fractures (average of 7 days). Most of the patients were advised toe touch weight bearing of the operated limb with the help of axillary crutches at suture removal, excluding 2 polytrauma patients and 4 patients with the opposite side upper limb or lower limb fracture.

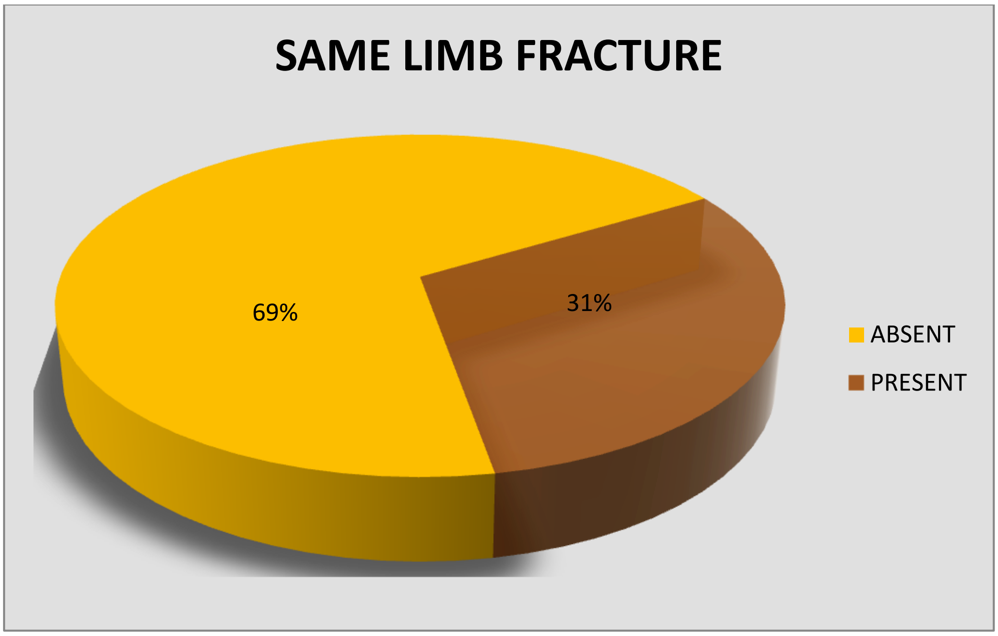


Diagram 11. *Pie Chart showing distribution of same limb fracture*

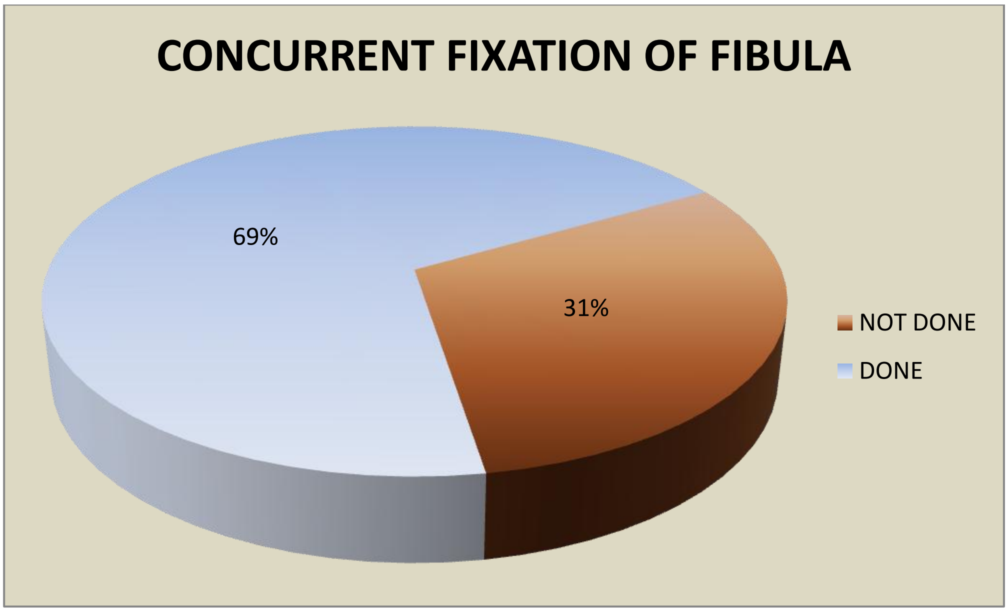


Diagram 12. *Pie Chart showing distribution of concurrent fixation of fibula*

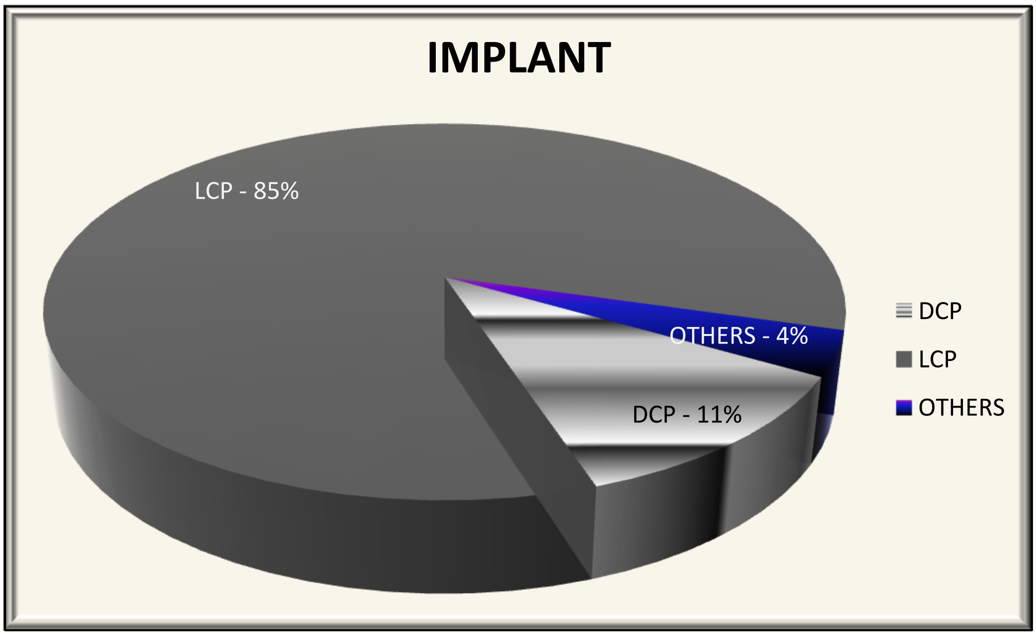


Diagram 13. *Pie Chart showing distribution of implant*

The average time to partial weight bearing was 2.87 months which was usually decided after radiographic evidence of some callus on routine x rays.Time to full weight bearing was on an average of 4.79 months.

The time to radiological union was slightly more for patients with associated fractures (average of 6.65 months) and open fractures (average of 6.67 months) as compared to closed ones (average of 5.6 months). Excluding 2 delayed unions the time to radiological union in our study was 5.68 months which is comparable to most western literature and studies.

None of the healed fractures had a varus/valgus angulation of more than 5 degrees or an anteroposterior angulation of more than 10 degrees.

Immediate post operative additional procedures were done in two patients which included two planned reverse sural flaps as cover for the soft tissue defect in open fractures.

There were 2 instances of culture positive infection. First one was in the immediate post operative period which was treated with appropriate antibiotics and an implant exit once bony healing was evident. The second one was a delayed infection (cellulitis) where the patient was managed conservatively with appropriate antibiotics and had implant removal on a later date.

On a total 7 patients underwent implant exit.

The average time taken to return to work was 6.31 ± 2.17 months. All patients went back to their previous jobs except for one patient who had to modify her job.

The mean AOFAS functional scores was 93 ± 7.3 (range : 69 to 100) and Olerud and Molander functional scores was 89.42 ± 7.79 (range : 70 to 100). The mean AOFAS functional scores were slightly better in males (mean : 94.16 ± 7.6) as compared to females (mean : 90.37 ± 8.4) , though not statistically significant.

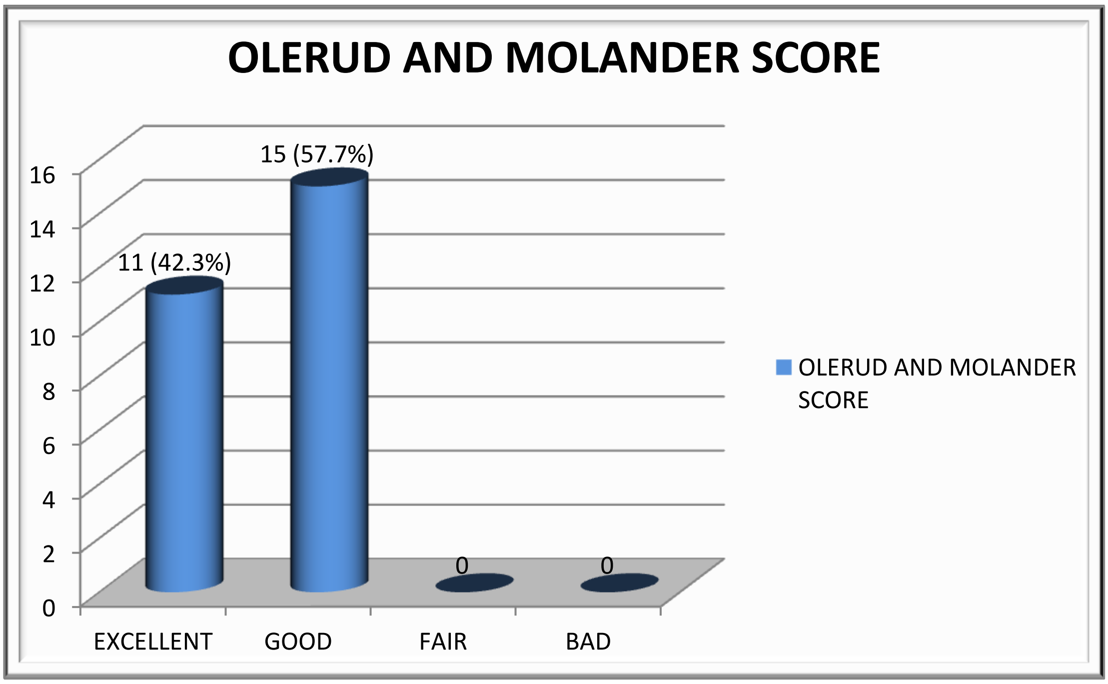


Diagram 14. *Bar Diagram showing distribution of olerud and molander score*

variable	group	n	%
AOFAS	0-30	0	0
	31-60	0	0
	61-90	7	26.92
	>90	19	73.08
OAMS	0-30	0	0
	31-60	0	0
	61-90	15	57.69
	>90	11	42.31

Table 2. *AOFAS and OAMS*

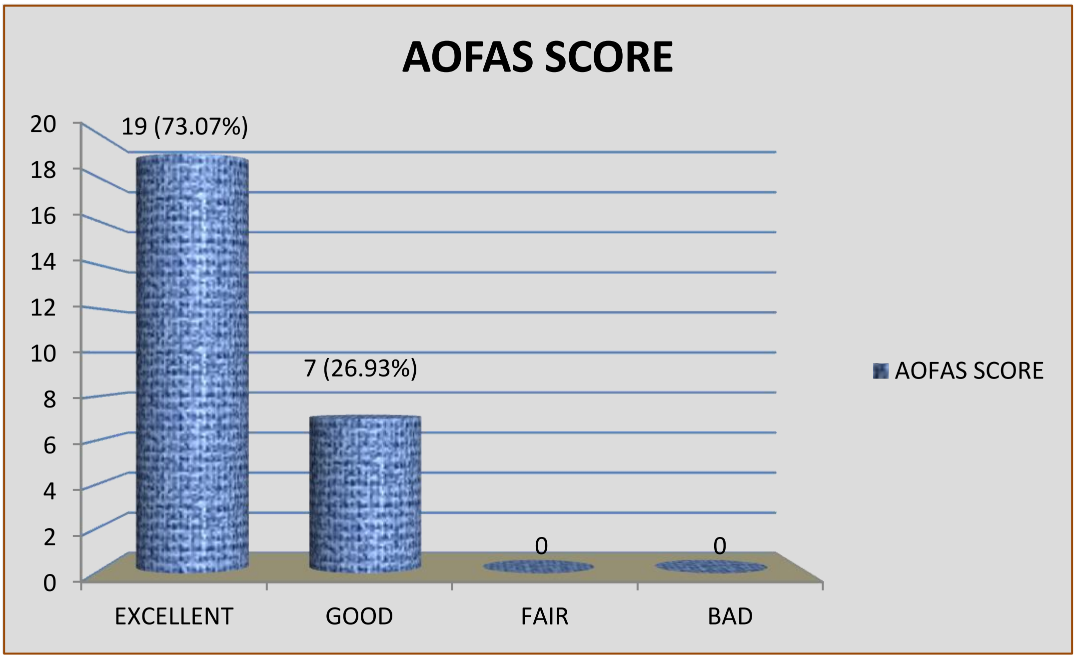


Diagram 15. *Bar Diagram showing distribution of AOFAS score*

	OLERUD AND MOLANDER SCORE
BAD(0-30)	0
FAIR(31-60)	0
GOOD(61-90)	15
EXCELLENT(91-100)	11

Table 3. *Olerud and molander score*

Statistical Analysis showed that the fracture pattern and the time to surgery are the only significant factors affecting the functional score. Rest of the variables like age, sex, comorbidities, concurrent fibula fixation etc... did not show any significant correlation.

The change of saggital or coronal angles from the immediate post op period till final follow up was less than 1 degree on an average (range 0 to 4.2 degrees).There was however a significant correlation between the change in angles and time to radiological union (p value = 0.03) even though it did not have any significant correlation with the functional scores as shown in the table and scatter plot below.

Correlation of difference in radiological angulation with the variables :

	coefficient	p-value
AOFAS	-0.26	0.18
OAMS	-0.15	0.45
Time to RU	0.42	0.03

Table 4. *Correlation of difference in radiological angulation*

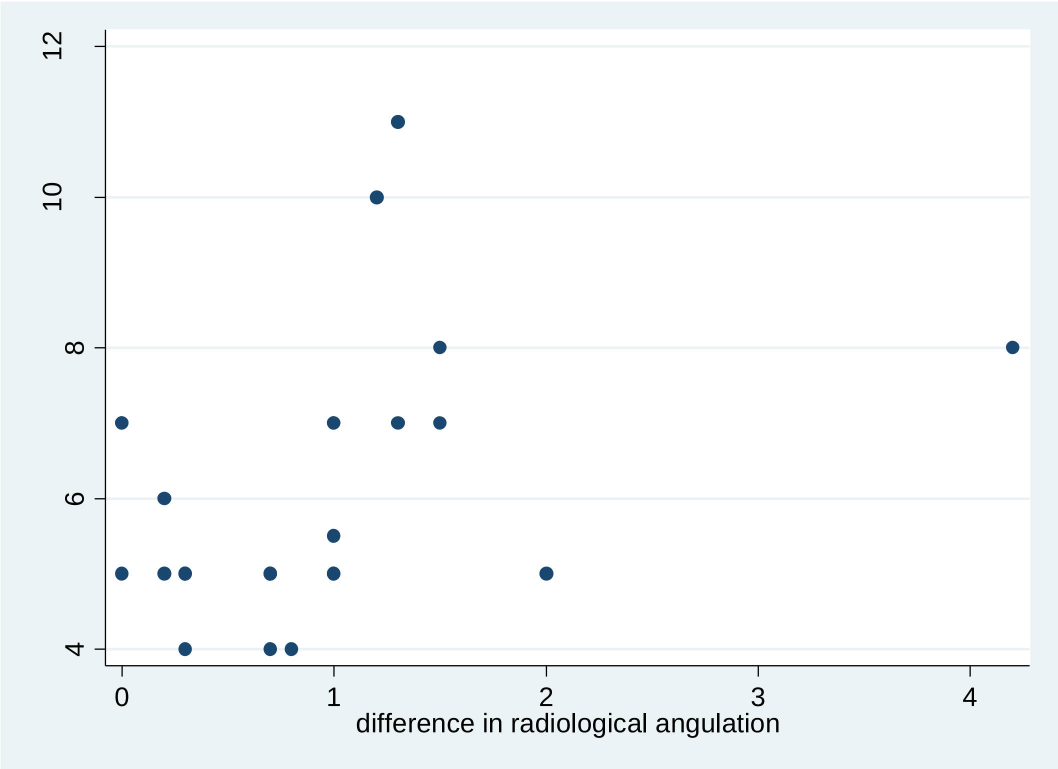


Diagram 16. *Scattered plot of difference in angulation vs time to union*

The change in the amount of varus or valgus angulation in the post operative period seems to be associated with the factor that the fracture is taking a longer time to unite.

The agreement between AOFAS and OAMS (Bland-ALtman plot) :

Variable	Pearson's correlation	bias(SD)	agreement limits
AOFAS vs OAMS	0.71	-3.57(5.96)	[-15.25, 8.11]

The OAMS underestimates the result compared to AOFAS. The pearson's correlation between the functional scores are not very high.

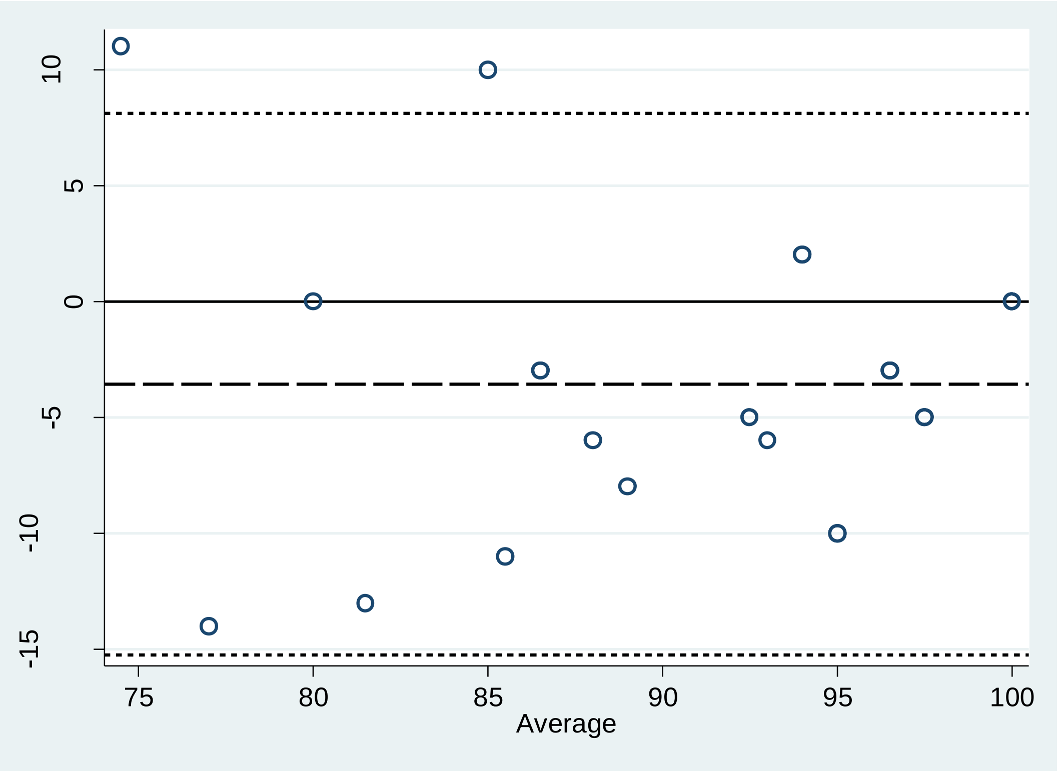


Diagram 17. *Bland-ALtman plot for OAMS vs AOFAS*

The average loss of ankle range of movement as compared to the opposite side was more than 30 degrees in only 3 patients.

All patients had fracture union with MIPO as the primary procedure. None of them required secondary bone grafting.

ILLUSTRATIVE CASES

CASE - 1

This 36 years old gentleman, met with Road Traffic Accident and had AO type A3 distal Tibia fracture of Right Lower Limb. The fracture was stabilized by using locked plate for the distal Tibia and distal Femur. Radiologically the callus was evident by 3 months. It progressed to good consolidation. His ankle range of movement was 20 degrees of dorsiflexion and 30 degrees of plantarflexion at the last followup (22months). He did not have any limb length discrepancy. Functional result of the patient was good.

Figure 14. *PRE OP AP*

Figure 15. *PRE OP LAT*

Figure 16. *IMMEDIATE POST OP AP*

Figure 17. *IMMEDIATE POST OP LAT*

Figure 18. *FINAL FOLLOW UP AP*

Figure 19. *FINAL FOLLOW UP LAT*

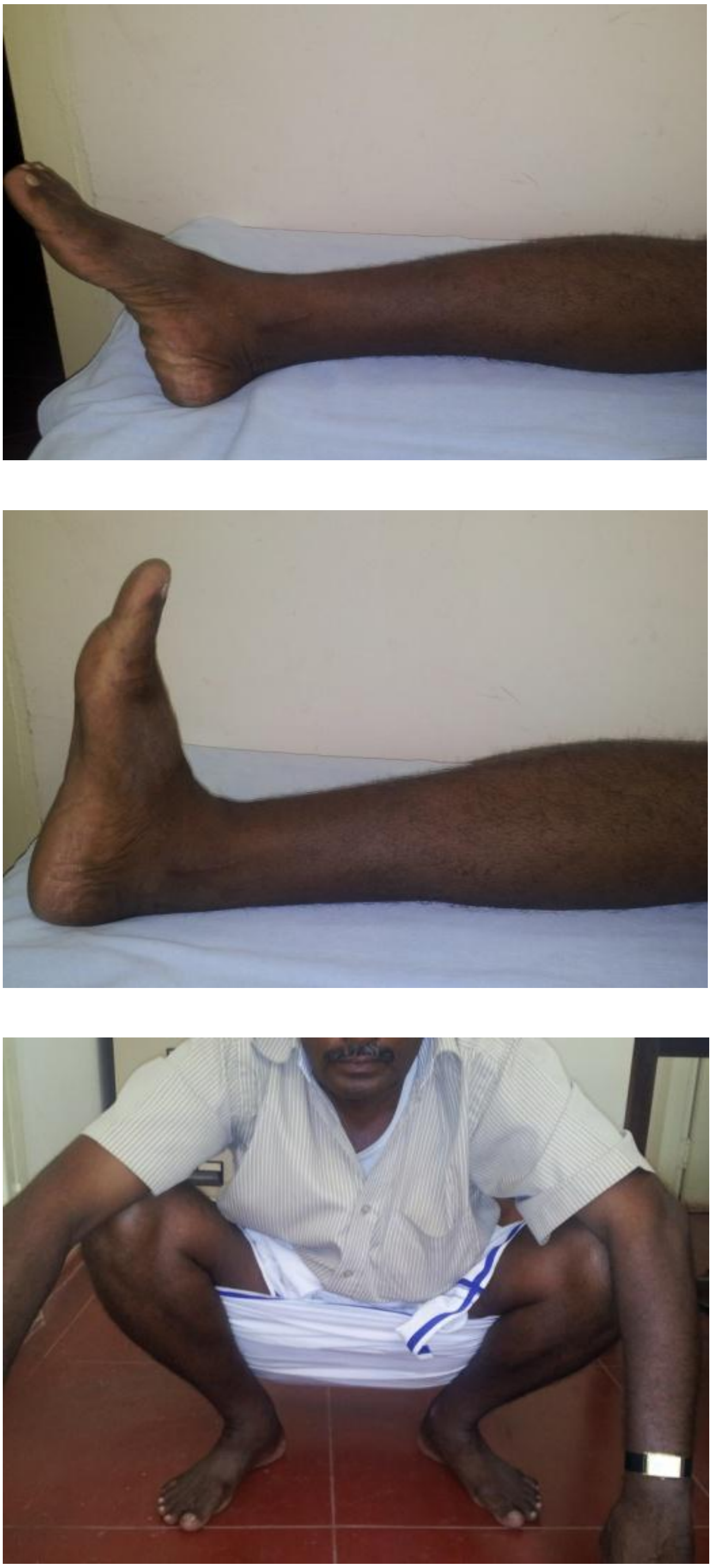


Figure 20. *Clinical photos of the above patient showing good range of ankle movements*

CASE - 2

57 years old lady sustained an open fracture of her left distal tibia (AO type A2) following Road Traffic Accident. The fracture was stabilized by using distal tibia L.C.P. and the fibula with a D.C.P. Post – operative period was uneventful. Radiologically the callus was evident by 12 weeks. She was walking full weight bearing by 4 months. At the last follow up (2½ years), she had normal ankle range of movement and no limb length discrepancy.

Functional result of the patient was Excellent.

Figure 21. *PRE OP (AP)*

Figure 22. *PRE OP (LAT)*

Figure 23. *IMMEDIATE POST OP (AP)*

Figure 24. *IMMEDIATE POST OP (LAT)*

Figure 25. *FINAL FOLLOW UP (AP)*

Figure 26. *FINAL FOLLOW UP (LAT)*

Figure 27. *Clinical photos of the above patient showing ankle range of movements*

Figure 28. *Soft Ttissue flap in a patient with open fracture(Case no. 7)*

Figure 29. *Implant Prominance in a patient (Case no. 11)*

Figure 30. *Clinical photos of patients with good range of ankle movements and functional scores(Case no. 17)*

Figure31 .*Clinical photos of patients with good range of ankle movements and functional scores(Case no. 20)*

Discussion

Innovative surgical techniques have developed over the years with improved understanding of biomechanics, biology and biomaterials, which have ultimately lead to better functional outcome for patients. Managing severely comminuted distal tibia fractures is a challenging task. The aim of this study was to assess the efficacy of minimally invasive plate osteosynthesis in the management of these injuries.

Fracture fixation using plate osteosynthesis is a demanding procedure and the success is related to the surgical technique used(71). A decade ago, more importance was placed on anatomical reduction and rigid fixation to achieve stability. The results were not so encouraging (i.e. increased incidence of delayed union and non union) due to violation of the soft tissue envelope around the fracture site. This led to evolution of newer technique which gave more importance to biology of optimal rather than maximal stability.

MIPO has gained wide application in the treatment of periarticular fractures of the tibia. Despite wide acceptance and assurance in possibilities of the procedure, most reports are based on a small number of patients and the investigators report differing rates of wound complications, time to union, malalignment, and function (Table 2), thus posing questions about whether the theoretical advantages are achieved. Our aims were to estimate the rate of union in tibial fractures treated by MIPO in our institution alongwith, the major and minor complications and functional outcome.

We did have follow up of 26 out of 32 patients treated with MIPO. Unlike other investigations with more strict inclusion criteria (e.g. fractures treated by single surgeon (60)), all patients treated with MIPO were included without regard for degree of soft tissue injury, terms of surgery, or experience of the treating surgeon. We believe this would be a better representation of the results for this treatment modality by the average orthopaedic surgeon.

Our study group included only extra-articular fractures (1 to 11 cms from the tibial plafond). Similar studies are scarce[66] because the mechanism of injury and prognosis is different in intra articular and diaphyseometaphyseal extra articular fractures.

	AOFAS		**OAMS**	
Variables Vs Scores	**correlation coefficient**	**p-val**	**correlation coefficient**	**p-val**
age	-0.16	0.44	-0.21	0.30
bmi	0.14	0.50	0.06	0.78
time indays(from injury to surgery)	-0.56	<0.001	-0.21	0.31
hospital stay	0.02	0.93	0.29	0.16
time partial weight bearing	-0.46	0.02	-0.22	0.27
time full weight bearing	-0.57	0.00	-0.23	0.27
time of radiological union	-0.09	0.66	-0.03	0.90
Average time to return work	-0.44	0.20	-0.24	0.24

Table 5 . *Showing correlation between demographic variables and scores*

The limitations of the study include the following. Firstly, ours is a retrospective study and has no controls. Second, a large portion of the patients (16 cases) was examined at 2 or more years after the injury, and patient answers about terms of restoring weight bearing or resumption of working capacity would be subject to recall bias and may be not accurate. Third, function in some patients could be studied at 24 to 48 months after surgery, whereas in other patients, the last examination was performed 1 year after surgery. Because function might improve after 1 year, our findings might underestimate mean function.

Another weakness is the fact that only the AOFAS scoring system was used to show functional outcome and no general health survey questionnaire (e.g., the SF-36) was incorporated into the study. The primary reason for not including a general health survey questionnaire was that at the beginning of this study none were being used to any degree in the trauma literature; another inherent weakness of the study is the small number of patients; this is an uncommon problem, making it difficult to build a large study population.

MIPO allowed uneventful healing in 84.7 % of our cases. Consistent with the literature, a high percentage of our patients resumed to their preinjury level of working activities with general restoration of lower leg function. However, complications occurred in a substantial portion of patients, which may be divided into three groups: disturbances of fracture healing (7.5 %), infection (both immediate post operative and late) (7.5 %), and hardware problems (26.9%).

High energy and comminuted fracture patterns took a long time to heal which is consistent with results of Collinge et al[38].

Milner et al[72] studied 164 fracture tibias with a long-term follow-up of 30 years and concluded that there were no significant univariate associations between malunions of the tibia and the development of osteoarthritis of the knee or ankle. In no patients in this series did we observe valgus or varus malalignment more than 5°.

One grey area of confusion in comminuted fractures is whether primary bone grafting is indicated or not. Primary bone grafting is contraindicated if soft tissue dissection has to be done to place the graft[18]. We have not done primary lone grafting in any of the cases. Bone grafting may be indicated if the healing is not progressive as assessed radiologically.

The explosion of technology and better understanding of the fracture healing help us to attain the optimal balance of stability and fracture healing.

Conclusions

Minimally invasive plate osteosynthesis is a good and safe technique for treatment of distal tibial fractures without intra-articular comminution providing fracture healing, rapid functional recovery, along with avoidance of major complications.

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Annexures

SL NO	NAME	AGE	SEX MALE(M)/FEMALE(F)	HIGH ENERGY(HE)/LOW ENERGY(LE)	FRACTURE OPEN/CLOSED	FRACTURE RIGHT/LEFT	PATTERN OF TIBIA FRACTURE	PATTERN OF FIBULA FRACTURE	AVG DISTANCE OF FRACTURE FROM TIBIAL PLAFOND (cms)	LAG TIME(in days) FROM INJURY TO SURJERY
1	MUR	41	M	HE	CLOSED	LEFT	A1	YES	9.7	12
2	VA	33	M	HE	OPEN	LEFT	A2	YES	5.4	1
3	MV	30	M	HE	CLOSED	RIGHT	A2	NO	5	1
4	RATK	36	M	HE	CLOSED	RIGHT	A2	NO	6.4	1
5	VIN	46	M	HE	CLOSED	RIGHT	A2	YES	4.7	1
6	AK	74	M	HE	CLOSED	LEFT	A1	YES	4.9	1
7	PJ	51	F	HE	OPEN	LEFT	A2	YES	4.3	1
8	JBK	26	M	HE	CLOSED	RIGHT	A2	YES	8.9	2
9	KM	58	F	HE	CLOSED	LEFT	A2	YES	7	3
10	MD	60	F	HE	CLOSED	RIGHT	A2	YES	5.8	3
11	SP	38	M	LE	CLOSED	RIGHT	A3	YES	2.6	2
12	U	40	F	HE	OPEN	LEFT	A2	YES	6.3	1
13	PM	35	M	HE	OPEN	RIGHT	A3	YES	5.4	120
14	NV	51	M	HE	CLOSED	RIGHT	A2	YES	3.5	6
15	SBP	34	M	HE	CLOSED	LEFT	A3	YES	2.8	8
16	GH	33	M	HE	CLOSED	RIGHT	A1	YES	7.3	1
17	MANI	55	M	HE	OPEN	LEFT	A2	YES	5.4	1
18	N	57	F	HE	OPEN	LEFT	A2	YES	3.9	2
19	SC	50	F	LE	CLOSED	RIGHT	A1	YES	5.4	10
20	R	21	F	HE	CLOSED	LEFT	A3	YES	7.9	2
21	VAL	50	F	HE	OPEN	LEFT	A3	YES	2.4	1
22	VD	27	M	HE	CLOSED	LEFT	A2	YES	10.9	12
23	RAJUK	54	M	HE	OPEN	RIGHT	A1	YES	9.3	6
24	S	22	M	HE	OPEN	RIGHT	A3	YES	4.7	2
25	PRTB	47	M	HE	CLOSED	LEFT	A1	YES	7.9	1
26	SB	36	M	HE	OPEN	RIGHT	A3	YES	5.2	5

Table 6.

SL NO	NAME	ASSOCIATED POLYTRAUMA	DURATION OF HOSPITAL STAY	FOLLOW UP (MONTHS)	PWB	FWB	TIME TO RAD. UNION	IMMEDIATE POST OP VARUS/VALGUS ANGULATION	FINAL FOLLOW UP VARUS/VALGUS ANGULATION	SCORE (AOFAS)
1	MUR	NO	6	20	4	5	10	-3.5	-2.3	EXCELLENT
2	VA	NO	7	39	3	4.5	7	1	2	EXCELLENT
3	MV	YES	4	54	4	5	7	-3	-4.5	GOOD
4	RATK	NO	8	64	3	5	7	1	1	EXCELLENT
5	VIN	NO	4	47	2	3	5	-2	-3	EXCELLENT
6	AK	NO	4	40	2	3	5	1	1.3	EXCELLENT
7	PJ	NO	14	29	5	7	8	-2.7	-4.2	GOOD
8	JBK	NO	8	48	5	7	7	2	3	GOOD
9	KM	NO	16	38	2.5	4	4	1	0.7	GOOD
10	MD	NO	8	32	2	4	5	-1.7	-1	GOOD
11	SP	NO	10	38	3.5	5	6	-1	-1.2	EXCELLENT
12	U	NO	12	22	3	7	11	-0.7	-2	EXCELLENT
13	PM	NO	14	55	5	12	8	1	-3.2	GOOD
14	NV	NO	21	70	2	3	5	-2	-1.3	EXCELLENT
15	SBP	NO	10	33	2	4	4	2	2.8	EXCELLENT
16	GH	NO	7	64	2	5	5	1	0	EXCELLENT
17	MANI	NO	7	64	2	3.5	5	3	3	EXCELLENT
18	N	NO	10	30	3	5	7	2	2	EXCELLENT
19	SC	NO	13	29	2	3	5	2	2.3	EXCELLENT
20	R	YES	13	23	2	3.5	5.5	3	4	EXCELLENT
21	VAL	NO	6	27	2	3	4	3	2.3	GOOD
22	VD	NO	19	27	3	5	5	7	5	EXCELLENT
23	RAJUK	NO	11	12	2	4	5	1	1.7	EXCELLENT
24	S	NO	10	14	3.5	5	5	5	5.2	EXCELLENT
25	PRTB	NO	12	20	2	4	5	-2	-2.3	EXCELLENT
26	SB	NO	11	22	3	5	7	2.4	3.7	EXCELLENT

Table 7.